THE GROUND-CUSHION PHENOMENON

UNIVERSITY OF MICHIGAN
JUN 2 - 1959
MAIN READING ROOM

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BEFORE THE

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THE GROUND-CUSHION PHENOMENON

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
Washington, D.C., Monday, April 13, 1959.

The committee met at 10 a.m., in caucus room, Old House Office Building, Hon. Overton Brooks (chairman) presiding.

The CHAIRMAN. The committee will please come to order.

Before we start with the hearing I have some regular business of the committee to take up. I will ask Mr. Ducander to read the list of appointments to the subcommittees.

I might say, before this is read, I have done my best to place members on those subcommittees which they had indicated they wished. In one or two instances, however, we failed, because of an effort to keep all of the subcommittees the same size, relatively. It was impossible to put each one on the exact committee for which he had stated a preference. However, I can assure the members of the committee that over a period of time the work of the committees will level off, and they will all approximate the same thing.

We will suspend our business here for a moment while the newsreel cameramen take some pictures of the whole committee.

We will take up the appointments to subcommittees after the next meeting.

The committee now will go into regular session. We will have to suspend all the pictures.

The first witness in this hearing is Mr. John B. Macauley, Deputy Director of Defense Research and Engineering.

Mr. Macauley, would you step forward, sir?

Mr. Ducander, I was out of town when this came up. Would you mind bringing the committee up to date on the hearing this morning?

Mr. DUCANDER. This morning the demonstration outside of the committee room was conducted by the Ford Motor Co. The first witness for the hearing this morning is Mr. John B. Macauley, Deputy Director of Defense Research and Engineering. The other main witness is Dr. Andrew A. Kucher, vice president, engineering research, Ford Motor Co. We have other backup witnesses who will be here and available for questions: Prof. Courtland D. Perkins, Forrestal Research Center, Princeton University; Maj. William H. Brabson, Office of Director of Defense Research and Engineering; and Mr. David Jay, Ford Motor Co.

Tomorrow morning at 9:30 there will be a Navy demonstration of the Aerophysics Co. developed test model. The witnesses will be as follows:

Rear Adm. R. Bennett, Chief of Naval Research.
Capt. A. B. Metsger, Deputy and Assistant Chief of Naval Research.
Dr. George B. Matthews, aero research engineer, Office of Naval Research.

Dr. Gabriel D. Boehler, associate professor of aeronautical engineering at Catholic University, and associated with Aerophysics Co.
Maj. J. L. Wosser, USMC, scientific officer, Air Branch, Office of Naval Research.
Brig. Gen. F. H. Britton, Director, Developments, Office of Chief of Research and Development, U.S. Army.
Col. G. P. Seneff, Jr., Chief, Air Mobility Division, OCRD.
Lt. Col. T. E. Haynes, Air Mobility Division, OCRD
Maj. Jack E. Downhill, USAF, Office of Deputy Director of Development, USAF.

Then, on Tuesday afternoon, if the House doesn't have business which will require the Members to go to the floor, there will be demonstrations by National Research Associates, Inc., and Spacetronics, Inc., at 1 p.m. outside the caucus room. The hearing will open at 2 p.m., with Carl W. Bollum, Sr., chairman of the board and president, Spacetronics, Inc., as the first witness. He will be backed up by Walter A. Crowley, vice president, Spacetronics, Inc.; John J. Klak, secretary and counsel, Spacetronics, Inc.; and Bruce Parker, Aluminum Co. of America.

The other principal witness is William H. Alper, president, National Research Associates, Inc. He will be accompanied by Melvin W. Beardsley, vice president, National Research Associates, Inc., and Paul Denn, Ordnance Tank Automotive Command.

That will conclude the hearings.

The CHAIRMAN. Fine.

The first witness this morning, as I said, is John B. Macauley, Deputy Director of Defense Research and Engineering.

Mr. FULTON. May I suggest this procedure: that we first hear the statements of all the witnesses, and then have the question periods when each one returns at a later time?

The CHAIRMAN. Is there any objection to that suggestion? If not, so ordered.

STATEMENT OF J. B. MACAULEY, DEPUTY DIRECTOR OF DEFENSE RESEARCH AND ENGINEERING

Mr. MACAULEY. Mr. Chairman and members of the committee, I appreciate the opportunity to discuss for you the ground-cushion phenomenon and the Department of Defense efforts to make use of this phenomenon in the design and development of new weapons and support systems. First, I will tell you a little about the ground-effect machines, then I will give you a classification of vehicles that use the ground-cushion phenomenon and the background and status of our research and development effort in this field. Finally, I will turn the discussion over to Army and Navy witnesses who will describe their programs.

Dr. Courtland Perkins, of Aerodynamics, at Forrestal Research Center at Princeton will be a backup witness for me with respect to the questions.

We have known for many years about the physical effect of operating fixed-wing aircraft in close proximity to the ground. For the sake of safety, however, the transition from ground contact to free flight as quickly as possible has been a goal of aircraft designers.

With the development of successful helicopters, the transition time from ground contact to free flight was reduced to seconds, but the advantage of obtaining lift augmentation from the ground effect while accelerating to translational lift became common practice in all helicopter operations. The lift increase due to ground effect was known to provide from 10 to 20 percent of augmentation for operations near the ground. The hovering ceiling both "in" and "out" of ground effect became design parameters of rotary-wing aircraft.

A number of factors have influenced the increase in interest of scientists and engineers in learning more about the ground cushion and its effect on air vehicles, particularly military aircraft.

First, the overall technological competition between the East and the West has demanded the investigation of any natural phenomena that might improve our military or economic systems.

Second, the increasing realization of the capabilitiy of an enemy to use nuclear weapons in any kind of conflict will require dispersal of installations and inhibit concentration of troops; consequently, our Armed Forces must have a much greater degree of mobility than ever before.

Third, the possibility that free world forces will have to fight in less-developed areas where inadequate transportation systems exist. This factor again indicates the need for increasing the mobility of military forces and reducing their dependence on such prepared facilities as roads, railroads, airfields and port facilities.

To a large extent, our effort to obtain military air vehicles that are not dependent upon prepared facilities breaks down into two categories based on the time required to obtain the vertical takeoff and landing, commonly known today as VTOL, aircraft capability desired. The present state of the art dictates that, to provide an immediate capability for tactical mobility, the helicopter be the vehicle procured. The Korean conflict caused accelerated development of this type of aircraft. Today, however, the Director of Defense Research and Engineering is coordinating a broad program of research and development to provide VTOL weapons and support systems.

These weapons and support systems are not bound by the range, speed, and complexity limitations of the rotary-wing aircraft. Although the helicopter will remain the most favorable configuration for certain missions, improved power-to-weight ratios of the modern gas turbine engines have accelerated interest in other configurations. Research aircraft programs have been establishd in a number of areas including tail sitters, convertiplanes, tilt-wing aircraft, and others. Upon the completion of current testing, design criteria are expected to be available for producing more suitable VTOL aircraft to meet military requirements for certain mission applications.

One of the more promising but less known areas of interest in the VTOL aircraft program is the ground-effect machine. Such a machine might be defined as a device which, at least in one phase of operation, derives a substantial portion of its support from a cushion of air sealed between the base of the machine and the ground. This seal can be realized practically by several different methods; for example, by means of a peripheral high-speed (annular) jet; a number of concentric cylindrical air seals called labyrinths; or, as with air bearings, by pure dimensions.

The use of the ground-cushion phenomenon by air vehicles may be classified into four categories:

First, the conventional airplane and helicopter and their more sophisticated VTOL derivatives that make the transition through ground effect very rapidly and make little beneficial use of the ground-cushion phenomenon. Practically all known flying machines fall in this category.

Next, the aerial-vehicle type of VTOL aircraft that operates within the ground cushion as a vehicle riding on air but, after obtaining a minimum velocity, functions as an aircraft and is supported by aerodynamic forces generated by its forward motion.

Third, a vehicle, sometimes called a minimum ground-pressure vehicle, that operates at all times within the ground cushion over open land or sea areas. The movement of this vehicle is not restricted by mud, snow, ice, or other similar surface obstacles that impede the movement of wheeled vehicles.

Last, a vehicle that operates on the air-bearing concept, which is that friction with the surface terrain is significantly reduced by a thin film of air between the surfaces of the vehicle and the support.

The reason for the military interest in ground-effect machines centers around the ground-cushion phenomenon. The first known U.S. Government experimental work which demonstrated this phenomenon was done by the Lewis Laboratory of the NACA. It was noted that by use of an annular-jet nozzle, that is, when high-pressure air is exuded from the periphery of a nozzle, unexplained thrust was obtained when the nozzle exit was less than 1½-nozzle diameters from a rigid surface; that is to say, from the ground.

Further experimental data indicated that with a specific amount of thrust, the lift obtained from an annular nozzle was several orders of magnitude higher when the exit was approximately one-half diameter from the ground. Let us take, for example, a turbojet engine and place it tailpipe down in a frame. Suppose that the complete frame, fuel, and engine weighed 1,000 pounds. Let us again suppose this engine was capable of producing 1,000 pounds of thrust. Now, let's pipe the exhaust into an annulus of 10 feet in diameter and assume that duct losses are negligible so that we still obtain 1,000 pounds of vertical thrust. Now, let's start the jet engine and run it up to 100 percent of power or 1,000 pounds of thrust. Since the vehicle weight is 1,000 pounds, the presumption would be that the vehicle would not rise. However, because of the ground-cushion phenomenon, the vehicle will rise to about 15 feet or 1½ diameters of the exit nozzle. When tied at a height of 5 feet by a thrust-measuring device, we find that approximately 2,500 pounds can be supported. Laboratory data have been obtained demonstrating this magnitude of lift augmentation.

Before we draw a conclusion that this is either fantastic or that we obtained energy from some outside source, let us use this same simple machine and compare its performance to other configurations.

We'll now remove the annular tailpipe and replace it with a straight tailpipe 2 feet in diameter and mount it 1 foot from the floor. Still assuming that 100 percent of power provides 1,000 pounds of thrust and that this test vehicle remains at 1,000 pounds in weight, we now find that the reaction of the jetstream with the ground at a height of one-half the diameter of the jetstream—that is 1 foot above the

ground—with a 2-foot exit nozzle provides a negative lifting capability. That is, the machine instead of rising as it does with the annular jet, reacts as if it weighed 1,100 or more pounds and, therefore, tends to be attracted to the ground.

Now, we can certainly conclude that some phenomenon is occurring because we know that this same test apparatus at significant distances from the ground will give us 1,000 pounds of effective lift just as it gives us 1,000 pounds of thrust when mounted horizontally.

Before leaving this test apparatus, let us make one more test. Let's put a turbine in the tailpipe and a shaft through the engine; then mount at 5 feet from the ground a 10-foot diameter helicopter rotor turning at optimum speed. Now, let's assume, since we're being very flexible with this test vehicle, that the rotor delivers 1,000 pounds of lift out of ground effect and the test rig still weighs 1,000 pounds. We now find that the rig begins to rise or that we must add approximately 500 pounds to the weight of the rig if it is to remain at a height of 5 feet.

For the sake of clarity, here is a simple chart of the experiments I have been describing. I believe it is fairly obvious that the lift and thrust factors, which apply in free air are obviously changed when applied in close proximity to the surface. The foregoing discussion explains what we mean by the term "ground-cushion phenomenon."

You see, the annular jet of 10 feet in diameter.

Mr. SISK. Mr. Chairman, could we have that put up on a tripod so we can see it?

The CHAIRMAN. Yes, we want the members to be able to see the chart.

Mr. MACAULEY. You will see from this chart the variation of lift capability, 2,500 pounds thrust of the annular jet, the helicopter with 10-foot rotor, and the turbojet with the 2-foot tailpipe. All three of these are the cases we have talked about.

There is another curve on there which you will see the 10-foot chamber, shown by the curve. That is the case which I think Dr. Kucher explained. This is what we call the air-bearing lift. You will notice the annular jet offers a capability above the ground to clear substantial obstacles with a width considerably greater than you would obtain with a helicopter.

In fact, if we flare the 2-foot tailpipe so it has a diameter of 10 feet, you have this ground proximity effect, which is similar to what Dr. Kucher has demonstrated for you, and about which he will talk later. The difference, of course, is that the relatively smooth surfaces, which rule out the cross-country military possibilities of such a machine, has certain other attractive features.

I have described for you experiments of the first three classes of ground-effect machines, but two other terms that will be used in this hearing should be explained.

Using our same jet-engine test rig, let's assume that we take the 2-foot diameter tailpipe and put a flare on the end so that it stands on its own flared stand, so to speak. As we operate the engine now, we note that the engine rises slightly and seems to float on a cushion of air or an air bearing. This engine can now be moved around the room with little effort. I understand that some of you have witnessed a demonstration similar to this, and to the Constellation type of

Hoover vacuum sweeper which uses this concept. If a similar device were mounted on a rail, since a very smooth surface is required, you would then have what the Ford Motor Co. calls their Levapad. This is the fourth class of ground-effect machine. I might add at this point, however, that because it must be mounted on a very smooth surface, this device is not attractive, from the mobility standpoint, for tactical military application.

A device being developed in Switzerland uses a combination of the annular jet and the air-bearing type of ground-effect machine. In this device, a number of concentric sheets of air that prevent total air leakage around the flange are used to obtain the same effect with the surface but at greater heights from the terrain. This method has been called the labyrinth seal.

To summarize, ground-cushion effects have been observed for many years, but, until we became interested in vertical takeoff and landing aircraft, these effects were never investigated for possible use. Sporadic investigations have been made during this decade by scientists and engineers for advantageously applying the ground cushion to hardware: All of these were conducted by the trial and error method. The Department of Defense, recognizing the military potential of ground-effect machines, is now coordinating the research and development activities of the services to provide an understanding of the ground-cushion phenomenon. In this manner, the Department of Defense can arrive at timely decisions to proceed with prototype developments that should result in significant increases in the combat effectiveness of the Armed Forces.

A technical review and analysis of known programs that make use of the ground-cushion phenomenon has been scheduled for early next month at the Forrestal Research Center of Princeton University, under Dr. Perkins' general supervision, and it is planned to conduct an international technical symposium later this year on the work being accomplished in the Western World on the ground-cushion phenomenon.

The CHAIRMAN. Under our resolutions we will forego the questions at this time, Mr. Macauley. You have with you Professor Perkins of the Forrestal Research Center of Princeton University. Does he have a prepared statement?

Professor PERKINS. No, sir.

Mr. MACAULEY. He is here for technical backup.

The CHAIRMAN. Do you wish to make a statement at this point, Professor Perkins?

Professor PERKINS. No, I don't want to add to anything that was said.

The CHAIRMAN. You think the statement is illuminating enough?

Professor PERKINS. Yes.

The CHAIRMAN. I am going to deviate just a little bit from our prepared program this morning by calling Dr. Andrew A. Kucher, vice president of engineering and research of the Ford Motor Co. I want to do that because I understand Dr. Kucher has to leave a little early, and we agreed to hear him as soon as we could.

You have a seat, sir. Who accompanies you?

Dr. KUCHER. This is David Jay, who is senior development engineer and project engineer on our efforts on levitation.

The CHAIRMAN. You are both from Ford Motor Co.?

Dr. KUCHER. Correct, sir.
The CHAIRMAN. Detroit?
Dr. KUCHER. Detroit.
The CHAIRMAN. Will you have a seat.
Dr. KUCHER. Thank you.
The CHAIRMAN. Do you have a prepared statement?
Dr. KUCHER. No, sir. As a matter of fact, I would like to talk generally and extemporaneously, since the invitation—which I appreciate—to meet before your group was presented last Thursday.

STATEMENT OF DR. ANDREW A. KUCHER, VICE PRESIDENT, ENGINEERING AND RESEARCH, FORD MOTOR CO.; ACCOMPANIED BY DAVID JAY, SENIOR DEVELOPMENT ENGINEER, FORD MOTOR CO.

I think I am sufficiently conversant with our own effort to talk extemporaneously. If that is agreeable, Mr. Chairman, I would like to emphasize the degree and extent within the automotive industry, and also particularly in our company, of fundamental research in basic concepts dealing with all modes of transportation.

We have a scientific laboratory and an engineering research organization that have magnificent facilities, representing some $25 million. They are engaged in advance projects, only. The budgets in that area represent about $20 million a year. In the scientific laboratory, particularly, we explore fundamentals and pursue them up to the point of technical feasibility. At that point they are transferred to the engineering research department, where physical development is pursued to determine whether there is practical adaptability. And it is in this area that the work on our levitation device was first instituted.

It was premised on this concept: First, let me make it clear that our approach, which has been referred to as the air-bearing concept, is not conceived of and is not adaptable as a private passenger vehicle, as such, or a road vehicle, because, as has already been pointed out, air-bearings raise the vehicle only a fraction of an inch above the ground, and the vehicle is not susceptible to free flight. However, the concept was predicated on an analysis of aircraft and the power-to-weight ratios that are imposed by the wings and tail section.

We find a fuselage form or body alone represents about 40 or 50 percent of the total drag in traditional aircraft configurations. So substantial economy can be effected in horizontal movements provided you remove the wings and tail section and overcome ground friction.

Further analysis indicated that wheels, which we have lived with for eons and eons, and will probably live with for a much longer period of time, are, however, limited in adaptability at speeds above 200 miles an hour. The logical alternative and basic thing here is substitution of the air-bearing concept. In approaching this concept we find air levitation can be provided for ground vehicles, ground-rail vehicles, vehicles controlled and guided by rails, and can allow speeds substantially in excess of 200 miles per hour. Our analysis, therefore, has resolved itself into configurations of vehicles that are from 6- to 40-passenger vehicles. Such a vehicle could be propelled by jet reaction or a gas turbine at speeds upwards of 300 miles an hour.

Now, one of the factors that governs the levipad effectiveness is the availability of the necessary air supply and pressure, and with a compound turbo machine those pressures are available. In other words, by bleeding a gas turbine, we have adequate pressure and supply that will permit levitation of vehicles economically within certain weight and power limitations.

Our present development is in the study phase to find the most feasible physical configuration for an experimental model. There is no presumption made on our part with respect to adaptability, either as a road vehicle, or as an immediate substitute for existing forms of intercity transportation. However, when you analyze the potentials in the latter area, you find that at speeds of 300 or 400 miles an hour, with transportation distances up to approximately 1,000 miles, you have a very substantial increase in the safety aspects and the operating economy.

Factors dealing with that subject are available, and I would be glad to have Mr. Jay and myself discuss them if they are important to you. In general, we believe firmly in the principle that air levitation for ground vehicles at speeds upward of 300 miles an hour is an economically practical concept.

Let me again emphasize the degree and seriousness of our involvements in basic research. It has generally been thought in years past that automotive engineering was essentially empirical. Vast changes have been made in the engineering structure, the internal engineering structures within the industry. And it would be a delight and a pleasure to have any of you gentlemen at any time visit our facilities and be exposed to the seriousness of our fundamental scientific effort in areas that transcend all phases of transportation, including the passenger vehicles, for example, in the area of lightweight and corrosion-resistant metals, high polymers and plastics.

Our scientific laboratory covers the sciences of physics, basic chemistry, electronics, and metallurgy and works generally in all basic research areas that have relationship to the fundamental economy of the company.

Again, I want to emphasize that our presentation here is not assumed to be anything but a revelation in those areas of interest that deal with high-speed rail-ground transportation.

One other remark I might make that will interest you gentlemen. We are also analyzing the other systems of air levitation, those which provide a vertical ascension in the same sense as previously described by Mr. Macauley. Our studies again relate to flyable vehicles rather than winged cars. The concept of an automobile with wings has been propagated for years and years. This is untenable. The concept, however, of a flyable automobile is not untenable, for the problems of increasing the available power-to-weight ratio and the further ability of instantaneous sensing of forces for corrective action are bordering upon accomplishment. Therefore, it seems to us the combination of those two fundamentals can be developed to provide a true "flying automobile." The near-ground movement of small vehicles is the first phase we are pursuing from the study standpoint.

The CHAIRMAN. Do you wish to elaborate on the practical usage or application of such an invention?

Dr. KUCHER. With respect to our levipad approach, the rail approach, I can emphatically state that the technical feasibility has been

established. In other words, all of the perameters dealing with the weight, the power equipment, the amount of engine needed to provide the air supply for levitation, are all within the physical domain. It now depends upon the completion of structures that experimentally support those basic physical facts.

The CHAIRMAN. Thank you very much, sir, Dr. Kucher and Mr. Jay.

You have a diagram you wish to explain?

Dr. KUCHER. Yes, I would like to show a drawing to the committee, a picture of our monorail concept——

The CHAIRMAN. If you would, stand behind that table.

Dr. KUCHER. In this rendering we show a ground rail, with the car gyroscopically balanced or air pressure stabilized on the rail. A suspended mono-rail system would work equally well. The factors that I described are attainable in either case. It is this general configuration we are now studying from the standpoint of a physical embodiment.

The CHAIRMAN. Thank you very much, sir.

I wish to thank Mr. David Jay for supporting you here in your testimony. Do you have any statement you wish to make, sir?

Mr. JAY. I think Dr. Kucher has covered the subject very well, representing my views. Thank you, sir.

The CHAIRMAN. We didn't cut you off in any way, did we, Doctor?

Dr. KUCHER. No, sir, but I would certainly be pleased to answer any questions that might be raised later.

The CHAIRMAN. When are you leaving to go back to Detroit, Doctor?

Dr. KUCHER. There is no particular urgency. If there is occasion, I can stay whatever time is required.

The CHAIRMAN. We will call on you for questions later.

Mr. WOLF. Could we see that drawing at this end of the room?

The CHAIRMAN. Yes. Doctor, if you could pass that around.

Dr. KUCHER. Yes, I think that would be satisfactory.

The CHAIRMAN. We have Maj. William H. Brabson, Office of Director of Defense Research and Engineering.

Major Brabson, will you come around, sir?

Major BRABSON. Sir, Dr. Macauley made our presentation.

The CHAIRMAN. We will call Mr. Macauley back for questions.

Mr. Macauley, I would like to ask you to tell us some of the practical uses you may find for the inventions you have referred to this morning.

Mr. MACAULEY. Well, I think, Mr. Chairman, that if you concede the possible employment of atomic weapons leads to dispersal of the Armed Forces, there is need for greater mobility of the Armed Forces over the ground in order to overcome the time effects in the dispersal. This is the sort of need to which the ground-effect machine makes a very promising approach since it enables you to cover reasonably flat terrain. You will recall the chart shows that with a 10-foot diameter rotor you could get an annular jet—which would provide clearance over normal obstacles. It would give you access, for instance, over marshy lands, over rivers, swamps, substantial increments of military entrance.

Dr. Perkins has a chart here which is perhaps considerably simpler than the one which I presented, and one which you might be interested

in examining. It is a rather small chart, but it simply indicates——

Dr. PERKINS. I might, if I may, say something about it. This little chart we drew up rather hastily last night to try to show you the difference in lifting capability between a helicopter, with its one-block lifting capability, versus a ground-effect carrier, which Mr. Macauley has indicated could be used by the Army, and which has a six-block lifting capability. In other words, it carries six times the load with the same power.

You are confined, however, to fly within a reasonable diameter to the ground. In this particular case, it would be limited to about 5 percent of its diameter. Of course, the bigger you make the diameter, the actual larger distance you will be off the ground. But it does show the enormous lifting capability that we are all just starting to realize might possibly be the practical use that Mr. Macauley was just discussing.

As I understand, tomorrow the military services are going to give you a lot of detail information on the potential uses of such machines. The main fact is that the machines can create large amounts of "lift" at finite distances above the ground, and they may prove useful militarily and commercially.

The CHAIRMAN. Can you tell me how far you have gone in the way of perfecting that machine?

Mr. MACAULEY. Well, there are only those research craft presently under development, Mr. Chairman, designed to see just exactly where we stand. The matters, for instance, of the stability and control of machines which by design fly low and slow, are something that calls for a good deal of attention. This is one of the fields which the Forrestal Research Center at Princeton, by contract with the Army, is investigating. We have no present weapon system, as such, but we have a research in various craft which the services will present to you. These will provide us with enough information about these effects to enable us to design a militarily useful machine.

Dr. PERKINS. I might add to that a little bit. I think that we can say that in this ground cushion phenomenon, we have again come upon something that most people knew existed, but never thought of in terms of a useful machine until very, very recently. As a result, we find ourselves trying to predict vehicles for the future when, as yet, all we know about them is that they can lift things. But as Mr. Macauley said, it is not only necessary to lift things, it is necessary to control these vehicles, and we know very little about this problem.

You notice that the automobile or the platform that was using the labyrinth in the Ford demonstration outside, was not under control. You just kind of slide across the floor. This problem will have to be solved by probably using a track, as Dr. Kucher suggests. However, if you get farther off the ground, the farther away from the ground you get the harder becomes the problem of stabilizing and controlling the device.

A lot of that work is yet to be done. We are not sure the solution will come soon. Therefore, you have to approach this with some caution, and I can say from the technical point of view that the Department of Defense program appears very adequate toward investigating the very important problems facing us before we are going to make this machine useful. And I think the committee should

recognize that we are really at the start of a program investigating these techniques, and I think that the program under Mr. Macauley is very well planned to solve the problems, if they can be solved.

The CHAIRMAN. You think it is worthy of continued research, then?

Dr. PERKINS. I certainly do. It is very worthy of continued research. I think the program, as it is presently laid on by the Department of Defense should be supported.

The CHAIRMAN. Mr. McCormack.

Mr. MCCORMACK. What do you call this machine?

Mr. MACAULEY. I think we call them "ground-cushion machines," broadly. The Ford device, I believe they call the "Levacar," or the "Levapad." The machines, the military research craft you will be exposed to tomorrow have various names, but they all operate within this same phenomenon, namely, that, if you are within a reasonably finite distance of the ground, you get additional lifting capacity; you can get very high lifting capacity if your clearance of the ground is very small. As you want to clear terrain for military purposes, you sacrifice some of the lifting capacity per unit of power in order to clear the obstacles on the terrain—the rocks, the gullies, and so on, that you may want to cross over.

Mr. MCCORMACK. Has this been given preferential status?

Mr. MACAULEY. It is a program we heartily approve of, and we are examining the service programs and integrating them so that we will have all the information from the Army and the Navy programs. We also are examining the program of the Air Force which to some extent is supporting this area. We want to be sure that we have an integrated defense program. It is a research program still, Mr. McCormack.

Mr. MCCORMACK. My question was, Has Dr. York given it a preferential status?

Mr. MACAULEY. It has not preferential status that I am aware of.

Mr. MCCORMACK. How long has this theory been known?

Mr. MACAULEY. I think ground-effect has been known for a long time. I would hesitate to say.

Dr. PERKINS. I think, from a practical point of view, and I have not heard this, I don't know whether people agree with me on this point, but I would date it about a year and a half or thereabouts. Maybe Major Brabson would have a clearer view.

Major BRABSON. The NACA report from Lewis Lab was published in 1957. They began their experiments in 1954.

Dr. PERKINS. I think my point was this phenomenon, as we now have it, in regard to a possible solution to vehicle problems, dates from about a year and a half ago.

Mr. MCCORMACK. Is this a form of a saucer?

Dr. PERKINS. Yes, that is right. You will hear of this program, I understand.

Mr. MCCORMACK. Of course, that has been known for some time, hasn't it? The NACA said back in 1947——

Major BRABSON. 1957.

Mr. MCCORMACK. Wasn't there a London company that approached some of our agencies over here as far back as 1950, on some theory of this kind?

Dr. PERKINS. I wouldn't be at all surprised, sir, you could date it back beyond that. I was only referring to a date when it really became universally accepted as an important thing to proceed with, although I am sure somebody thought about it before.

Mr. MCCORMACK. Can you answer my question, Mr. Macauley, whether as far back as 1950 some kind of a saucer was taken up with some of our agencies of government?

Mr. MACAULEY. I don't think that it dates quite as far back. If you and I are thinking of the same thing, the Avro did approach our military services, but my recollection is that this was about 1955, sir.

Mr. MCCORMACK. AVRO is a Canadian company, isn't it? The Canadian company of A. V. Roe?

Mr. MACAULEY. Yes; it is a subsidiary of the A. V. Roe Corp.

Mr. MCCORMACK. Is the Air Force furnishing funds to the AVRO Co. of Canada in connection with this?

Mr. MACAULEY. The Army has the contract at the present time.

Mr. MCCORMACK. If any questions asked are classified, I don't want you gentlemen to answer them now.

Mr. MACAULEY. The Army has such a contract, Mr. Congressman, but I think I would rather not take their thunder. They will appear before the committee tomorrow with full details and, I hope, with some demonstration of their device.

Mr. MCCORMACK. Of course, the question of "thunder"—you don't mind if we try to get the facts when we can. You know what the Army is doing, though?

Mr. MACAULEY. Yes; sir, I do know what the Army is doing.

Mr. MCCORMACK. Are you competent to testify on that?

Mr. MACAULEY. I think there is just one report which is classified, sir, which would call for a closed session. I think that is correct.

Mr. MCCORMACK. When did the Army make the contract with AVRO of Canada?

Mr. MACAULEY. It is my recollection that this was——

Major BRABSON. 1958.

Dr. PERKINS. 1958.

Mr. MCCORMACK. Well, hasn't some form of a saucer been discussed prior to that? You say 1955, something about Avro?

Major BRABSON. This is a classified answer, sir.

Mr. MCCORMACK. That is classified?

Major BRABSON. Yes, sir. This deals with a different type of vehicle altogether.

Mr. MCCORMACK. So I can't go prior to 1955?

Major BRABSON. No, sir.

Mr. MCCORMACK. Can you tell us how much money has been supplied to AVRO? Is that classified?

Mr. MACAULEY. No, sir. The total funds have been about $5½ million, I think, to AVRO.

Mr. MCCORMACK. It is really basic research?

Major BRABSON. Yes, since 1955.

Mr. MACAULEY. Since 1955.

Mr. MCCORMACK. What benefits can flow from the military end?

Mr. MACAULEY. I think substantial benefits can flow from any bit of new knowledge, which indicates that we can augment the now available lift for a given horsepower by a factor of four or five or

six. This is an important area to us who want to move freely if we are willing to move close to the ground.

Mr. McCormack. Now, is the Army furnishing money to the Ford Co.?

Mr. Macauley. No, sir.

Mr. McCormack. They are doing it on their own?

Mr. Macauley. The Ford Co. studies—I will let Dr. Kucher answer that.

Dr. Kucher. Mr. Chairman, it is an internal effort entirely.

Mr. McCormack. They are probably looking ahead for a new automobile in the air, aren't they?

Dr. Kucher. No.

Mr. McCormack. I would admire them if they were.

Dr. Kucher. We are restricted to the rails at the present time.

Mr. McCormack. I know at the present time, yes.

Dr. Kucher. Indeed, you are correct.

Mr. McCormack. What is that?

Dr. Kucher. We hope some day to have a flyable automobile, if you please, rather than a roadable airplane. These are different, fundamentally. Again, you are in that philosophical area of concept. Our convictions are that a flyable automobile is feasible, provided the power-to-weight ratio is great enough and your anticipatory sensing can direct the necessary control. We reject the concept of widespread wings and ailerons as necessary for achieving stability in flight.

Mr. McCormack. In other words, the Ford Co. is looking into the future?

Dr. Kucher. Indeed, it is.

Mr. McCormack. That is a serious question, and a very important question, too. I am thinking of the economic impact of these future developments upon peoples and individuals. The new economic system that might develop, the wiping out of billions of dollars of invested capital in what are now up-to-date activities, but which would be completely outdated in the world of tomorrow. I assume those are broadly some of the thoughts, applied not only to this mode, but telephone, television, and everything should be looking ahead; is that right?

Dr. Kucher. That is right, sir.

Mr. McCormack. My questions are not critical, but to try and get information, because I think this gives me an opportunity to assist in one of the real services of a congressional committee in Congress, which is to try to disseminate information for the thinking of the people.

Furthermore, the very survival of a democracy might be involved, because we have to gear it, channel it to serve, rather than to master. Are those some of the thoughts?

Dr. Kucher. Yes, sir. As a matter of fact, your observation on the economic implication is of enormous weight.

Mr. McCormack. I can assure you, I innocently trespassed, but I can see these things.

Dr. Kucher. Indeed.

Mr. McCormack. I am not questioning. I think it is a very good idea to explore from the research angle all aspects. Are any other companies looking into this that you know of?

Major Brabson. A number of companies; yes, sir.

Mr. McCormack. Are they doing it on their own?

Major Brabson. Some of them are and some of them aren't.

Mr. McCormack. I suppose they are looking into other aspects of basic research, too?

Major Brabson. Yes, sir.

Mr. McCormack. Well, I think that is all. I have enough.

The Chairman. Mr. Fulton.

Mr. Fulton. We are glad to have you here. Any one of the witnesses can answer my questions.

It does give some of us a new direction of thought, and I believe the questions by the gentleman from Massachusetts have been lifting the sights of every one of us on the committee.

It would strike me that if we need mobility of forces abroad for our Department of Defense, we would likewise have to have them in this country. Therefore, I would think that we would as soon as possible have to have some system of monorails all over this country for the movement of war traffic forces and strategic materials in case of an emergency. Are you giving any study to that?

Major Brabson. Sir. I would like to go back to the prepared statement.

Mr. Fulton. I am limited to 5 minutes. So if you can hurry up with the answers——

Major Brabson. We have discussed four different types of ground-effect machine. These are the airplane and helicopter, as a conventional machine, which use the ground effect as a transitory nature only.

Mr. Fulton. Will you answer on the point: Have you considered a 200- to 300-mile-an-hour system of monorails using this cushion of air process maybe in conjunction with our present railroads or bus systems? Have you considered such? If you have, say yes. If not, no.

Major Brabson. No, sir, not by the Department of Defense.

Mr. Fulton. Then it would bring up the question to me, on our present runways of our airports; why couldn't you have the system on the ground of an air cushion on the runway so that there could be no more plane crashes on runways? You could have an instantaneous perception of the force coming in, and immediately get corrective action at the particular location necessary. Why not? Have you done anything on that? Just say yes or no, and let it go at that.

Mr. Macauley. I think we are laying in these research aircraft——

Mr. Fulton. I want to go much quicker than that. Have you done that or not?

Mr. Macauley. We have not, no.

Mr. Fulton. All right. It would then be possible, likewise, in planes, to have some sort of a system of rockets that could be made directional, that in the event of trouble they could be released as the airplane almost came into contact with the ground, and again no more plane crashes anyplace; isn't that possible? Just answer the question "yes" or "no".

Mr. Macauley. I must say that I don't think I know. It is pretty well outside the frame of what we are talking about.

Mr. Fulton. Seaplane landings; one of the troubles is—I was in the Navy—air—1942–45—in hitting an unexpected heavy wave; you

could likewise have this instantaneous perception that has been spoken of here, not of forces, but of surfaces. We in Pittsburgh have found that our whole transportation system is bad, our mass transportation system, so beginning this week in the house of representatives and the senate, in Harrisburg, Pa., there is a new bill going through for a new transportation system under a public authority, combining everything.

I would like to alert the companies here to get in touch with them, because we have hills 500 feet high, we have rivers, we have valleys, and this would be a perfect thing for us to start in new.

And secondly, from the military point of view, you ought to be looking to it because with a tremendous city like Pittsburgh, with only, say 15 bridges and about 6 tunnels to get out through, we would never get out if there was an emergency threat.

I have two more minutes here. Let me go into something else.

Mr. McCormack. Could I ask the gentleman to yield one moment?

Mr. Fulton. Yes.

Mr. McCormack. Projecting your minds into the future, any one of you gentlemen, when do you foresee, in time, some practical use developing from this theory?

Mr. Macauley. In the period of 1965–70, in that period, I would say.

Mr. McCormack. What do you see? What can you see then, any one of you gentlemen? The gentleman from Ford, or anyone.

Dr. Kucher. May I express myself? I would allow that with a meager premise——

Mr. Fulton. Why don't you come to the table?

Mr. McCormack. I like these family affairs.

Dr. Kucher. Fine.

I would allow, gentlemen, that with the further technical substantiation of the factors we are working with now, with the design of a monorail vehicle as a preliminary approach, a short rail system, that that phase of it could be accomplished within possibly a 5-year period; that practical adaptability on any large scale certainly would not be within less than a 10-year period. There are just that many problems involved.

Would you subscribe generally to that?

Dr. Perkins. Yes.

The Chairman. Mr. Fulton.

Mr. Fulton. I have 2 minutes, yet.

Now, the other question is this: Has there been any research done on nose cones on reentry, for reentry purposes of missiles? I was down with the others on the committee at the Army Ballistic Missile Agency at Huntsville, Ala., and I was struck with the fact there was such a friction with the oblating materials. I have several times said, "Why don't you use a cushion of air; that is, either generated in the vehicle or by a labyrinth, or by tubes at the edges, so that at the point of the greatest friction, you have a lubricant; that is, the liquid or the gas of the same type which is the best lubricant.

Has any research been done on that, using air as the lubricant on a guided missile reentry?

Mr. Macauley. Dr. Perkins.

Dr. Perkins. There has been almost that as you described it.

Mr. FULTON. They shouldn't have smiled and chuckled or laughed at me a little bit, should they?

Dr. PERKINS. Did anybody?

Mr. FULTON. No; down there they did.

Dr. PERKINS. Actually, there has been research done on ejecting a gas out of the nose of those cones to change the conditions at the front end, that would transfer the heat from the nose. This is a study going on at the present time.

Mr. FULTON. I would like to hear about that later. I have part of 1 minute. Are those high fins necessary? It looks like the Ford tail-lights on that thing are pure decorations.

Dr. KUCHER. No, sir. As a matter of fact, the fins are an essential factor in this design, aerodynamically, because they deal with the center of pressure travel, and the stability in yaw has to be established by means of fins. The four ports at the rear, although they have those little red things on there, they represent the exhausts from the propulsion system.

Mr. FULTON. So they are really not taillights?

Dr. KUCHER. No, sir.

Mr. FULTON. They are not necessary like high fins are necessary on automobiles, are they?

Dr. KUCHER. No, sir; not in the same sense. This aerodynamic lift over the top of the configuration is restrained by those particular fins.

Mr. FULTON. That design isn't particularly necessary, is it?

Dr. KUCHER. That is one configuration that has a high aerodynamic efficiency.

Mr. FULTON. It wouldn't sell, though, would it?

Dr. KUCHER. Hardly.

Mr. FULTON. It has been stated a smooth surface was required for this type of an air-cushion vehicle. I don't believe that is correct. I would say if it is an annular or circular jet, and the streams were vertical, that that is correct, but I don't think it was taken into consideration that the streams of air might be not vertical, but variable and directional; and secondly, they might have Vernier rocket attachments; and thirdly, you might have something where the thrust varied so that it wouldn't be a continuous and equal thrust.

Fourthly, I would say that if you could have instantaneous perception of the forces that might be encountered for corrective action, you could certainly have a system of instantaneous perception of surfaces for corrective action.

Under those conditions, I think if you put some research in that, there might be a possibility. Thank you. That is all.

The CHAIRMAN. Mr. Teague.

Mr. TEAGUE. Mr. Macauley, is there such a thing as a flying saucer?

Mr. MACAULEY. Well,——

Major BRABSON. It is not flying yet.

Mr. MACAULEY. One of these research machines, Congressman, will be very saucer-like in appearance, but it isn't flying yet. We hope to have it flying.

Major BRABSON. A number of models are flying.

Mr. MACAULEY. We have models which are circular plan-form airplanes, if you want to call them, or circular plan-form ground vehicles, and they certainly look like saucers.

Mr. TEAGUE. Mr. Macauley, is there such a thing as a flying saucer?

Dr. PERKINS. In outer space he means.

Mr. MACAULEY. We don't have any flying saucers, sir, except this one research vehicle, which we hope will be a flying saucer.

Mr. TEAGUE. You still haven't answered my question.

Mr. MACAULEY. I would like to have you decide whether this flying saucer is something we have, in which my answer is no, or whether it is something from outer space, to which I guess my answer is still no.

Mr. TEAGUE. Do you know whether there is a flying saucer?

Mr. MACAULEY. Not to my knowledge, sir.

Mr. TEAGUE. Those are all the questions I have.

Mr. MCCORMACK. That is, you haven't seen one? That is as far as you want to go.

The CHAIRMAN. Mr. Sisk.

Mr. SISK. I would like to ask Mr. Macauley this question:

With reference to this ground-cushion phenomenon; does it have any relation to the so-called escape corridor? I actually don't recall the name of it, but some time ago there was quite an article, in Aviation Week, or some other aviation magazine, and this is dwelled on from time to time, concerning a phenomenon which exists at a little higher altitude than you are talking about here. I am curious to know whether your experiments indicate any relationship to, and that has to do with the experiences, for example, of Pan American pilots, I think Trans World, and possibly a few others, where, due to damage or loss of engines are more or less fighting for their lives to try to get a plane in, they found a corridor at say 89 feet, 90 feet, 95 feet, at which their fuel consumption immediately dropped, their power increased, the possibility—in fact, the planes were brought in from overseas, from over water, that otherwise apparently would have been impossible.

Are you familiar with the thing I am talking about, this phenomenon, which I understand is still in the realm of the unknown to some extent?

Dr. PERKINS. There is a real effect, and it is known. This is known as the influence of the ground on the induced flow over airplane wings. It has been known for some time that it is much easier—you have less drag right next to the water than you would away from the water. It is a ground effect on the induced flow from the wings. It reduces the drag a little bit. Therefore, it will increase your range under conditions—certain conditions. It will increase your range. This was well documented by Charles Lindbergh in his book. He used this effect going across the Atlantic at times. He flew right down on top of the water to use, as he quoted it, "the ground-cushioning effect" to reduce the drag. This is well known.

Mr. SISK. Well, I know there have been quite a number of tests made. I understand even within the past 6 or 8 years there have been a number of tests made on it. I am curious—does it have any relationship to the same type of ground-cushion phenomenon you are describing here?

Dr. PERKINS. In a different sense, it is the same sort of thing.

Mr. SISK. In a different sense, but it is the same sort of thing?

Dr. PERKINS. Yes.

Mr. SISK. As I understand, these tests or experiments, which are carried on by some west coast firms some time ago, indicated this application varied in over water tests, depending upon the depth of the water, and so on, and its proximity to land.

Dr. PERKINS. No, I don't think so. I don't think there is any such effect. It is purely proximity to some surface. It doesn't matter whether it is land or water, and it doesn't matter how deep the water. It is purely the fact there is a finite surface present that gives this effect. That is why these ground-effect machines we talk about can be used over land, water, mud, ice, snow, as long as there is a surface.

Mr. SISK. The particular article I recall indicated some results obtained were due to the proximity of land areas, or possibility of land in relation to the depth of the water. Maybe I am wrong, or maybe the writer of this article was purely surmising, but I was interested only to what extent those experiments and those tests were tied in with the things you are doing in this ground-cushion phenomenon.

Dr. PERKINS. The phenomenon, as I was describing it, is definitely tied in, and is part of our experiments. It is a well-known, documented, scientifically proven fact, and is part and parcel of the scientific aspects of this program.

Mr. SISK. Thank you.

Thank you, Mr. Chairman.

The CHAIRMAN. Any questions down on the right?

Mr. HECHLER. Professor Perkins, and Mr. Macauley, early next month there is going to be a technical review and analysis of the program on this phenomenon. I wonder if you can tell us how long this analysis will take, and what is involved in it?

Dr. PERKINS. Well, earlier, I mentioned the fact, and I think the most important aspect of this program is that it is kind of a well-organized frontal attack on the problem that remains, or on the problems that remain. Everybody has gone off very enthusiastically investigating various parts of the program.

It became obvious to the Department of Defense that somebody ought to coordinate this to make sure people weren't all doing the same things, or at least the research program is broad enough to cover all aspects. Therefore, it was suggested by the Department of Defense that the Air Force, Navy and Army get together using Princeton as headquarters thus coordinating this program to make sure that it is a well-organized general program covering all aspects.

This is scheduled for May, and then in October, as I understand it, we hope to pull together an international symposium where we will have the benefit of the whole Western World's thinking on the solution to some of these technical problems that we are now looking for.

Mr. HECHLER. I am sure the committee would be very interested in the results of this analysis which you are making. I would like to compliment the Department of Defense on being associated with the Forrestal Research Center in Princeton and having contracted for the services.

Dr. PERKINS. Thank you very much; just because you and I went to the same college, you don't have to say that.

The CHAIRMAN. Any further questions?

Mr. FULTON. Yes.

The CHAIRMAN. Mr. Fulton.

Mr. FULTON. Has any other application been thought of for this particular principle?

Dr. KUCHER. May I speak to that, Mr. Fulton?

Mr. FULTON. Yes.

Dr. KUCHER. It is somewhat amusing. We, of course, referred to this as "glideair".

Mr. FULTON. As what?

Dr. KUCHER. As a "glideair" vehicle. We received a communication from one of the aircraft companies informing us that we had—well, "usurped" or improperly used the term, since there was a loading system, an airplane-loading system developed that used this name. A brochure was sent to us describing the system. It is a very effective method for warehousing and loading freight in aircraft, in which the floor surface or deck of an aircraft has a lot of orifices in it that are valve-controlled. Spring-loaded steel balls seal the orifices, you might say. Compressed air fills the space under the floor. As you push a skid over the deck, those balls are depressed, and air is admitted under the package, under the skid and allows it to be moved within the aircraft. I don't know what the extensiveness of this application has been, but as a result we conceded, and that is why we are now calling our development the "Levacar" rather than "glideair".

Mr. FULTON. I thought it might be used to prevent head-on collisions of motor vehicles. When two vehicles were going to collide head on, but if each had electronic eyes, these could trigger instantly, and divert the cars so they couldn't possibly get within a certain number of feet of each other at the speed they are moving.

Dr. KUCHER. May I suggest there would probably be more direct mechanical methods that would be much more effective than the reaction of an airstream—I mean braking systems, and things of that character, that might be controlled.

Mr. FULTON. You could flip one car up in the air; you put the pressure on, up she goes.

Dr. KUCHER. We will wait a little while for that one.

Mr. FULTON. You did it for me out there, why don't you do it on a car? You are losing 37,000 people a year, and you people haven't done a darned thing in trying to prevent head-on collisions, with something like this. Why don't you do it? You aren't doing very much on this thing.

Dr. KUCHER. As I say, I believe from the standpoint of head-on collision prevention, there are better mechanical methods.

Mr. FULTON. Why aren't they in effect? This looks good to me. I would say, "Boy, pop up every time you are going to have a collision"; we would put you up over it, and down on the other side. I would sell autocars on that.

Dr. KUCHER. We are investigating more direct methods.

Mr. FULTON. Why don't you investigate this? I am trying to say this is the method.

Dr. KUCHER. That may be an appropriate thing to pursue.

Mr. FULTON. Will you try it?

Dr. KUCHER. I certainly will investigate it.

Mr. FULTON. I think it is appropriate, with those high fins you are putting on that car. I think there should be more research put on preventing these 37,000-a-year deaths from motor vehicles, and ap-

plying some of these new principles of research to safety, rather than to say, just make them go 300 to 500 miles an hour. That is the thing that shocked me about the testimony this morning. It is all about how to go faster, and how to go farther, but there hasn't been one word of how to make it safer if we do that.

I feel if I am having some impact here this morning, that you should likewise put just as much effort on the safety factor of it.

Dr. KUCHER. May I suggest that it would be extremely desirable to have you and others visit our laboratories and see some of the electronic controls that we have under development. The reason we don't have them applied is that they have certain deficiencies that have not been solved, but the degree and extensiveness of our interest in safety is paramount, far more so than our interest in air levitation.

Mr. FULTON. I am so glad you are here, because I would never in the world have ever gotten to see or talk with you. I often thought, why don't you have automobiles that will have sort of a V-type or a snowplow thing built in the midfront, so that they will sheer off two wheels. Suppose two cars met, and they each had a snowplow effect in front, they would just sheer off one part, and sheer off the other part, and divert each other, instead of going "crash," and everybody going through the windshield; have you thought about that?

Dr. KUCHER. No, sir; you have suggested many concepts worthy of pursuit. Basic invention is the thing that initiates these programs, and the thing that you last mentioned is something I don't recall having been presented with at any time in the past.

Mr. FULTON. Or did you ever think, maybe, on automobile tires, if you get into trouble and your tire is down in a hole, what you do is put a jet on and it comes out through some part of the tire and lifts your wheel right up and you don't even need a jack.

Dr. KUCHER. No.

Mr. FULTON. Maybe you'd better try that, too.

The CHAIRMAN. Thank you very much, gentlemen.

I especially want to commend the Ford Motor Co. for its fine program of basic research with the expenditure, as I understand, of some $20 million to $25 million per year.

While you are here, the committee is interested in the general sense of basic research. Could you give for our record an idea of the number of employees you have engaged in research and development. You have already given us an idea of your overall expenditure. We want that tabulated in reference to other privately endowed research developments.

NOTE.—The Ford Motor Co. reports that there are 1,500 employees engaged in advanced research projects.

I want to commend, too, Princeton University here, represented by Dr. Perkins, for taking part in this basic research program. I want to get everybody interested in the program.

Mr. Fulton has another question.

Mr. FULTON. I wanted to ask the professor: When the vehicle, the other car, what do they call the other one?

Dr. KUCHER. Scooter.

Mr. FULTON. Scooter, when that gets up so that it is in a fixed point in space with no contacts with the ground, what is the situation? Is that a place where the lift equals the gravity and the thrust equals the drag? Are the forces all in complete balance at that point?

Dr. PERKINS. You mean at rest?

Mr. FULTON. At a fixed point.

Dr. PERKINS. The answer is "Yes."

Mr. FULTON. So it is just the same as it would be if it came to a stall point of a plane, the plane just gets to a certain point, it would be just in stall, when the plane starts down?

Dr. PERKINS. At that point the wing of the airplane loses its lift, then the lift doesn't equal the weight.

Mr. FULTON. What I am trying to get at is, when you then start it, what kind of a mass reaction do you have? Is it very hard to get that started from that fixed point, or is it better to start it up on an arc and keep it moving? You wouldn't just go up and start it out, would you?

Dr. PERKINS. You could, but it is always more efficient to start off as you suggest, if it has any lifting capability at all, to use whatever lifting capability to help it. It is expensive to just blow yourself up.

Mr. FULTON. How would you stabilize it? With Vernier rockets, or lateral air pressures, or would you have——

Dr. PERKINS. It depends on how far away from the ground you are trying to stabilize it. The Ford machine is probably quite stable in its present configuration. As you noted, it tended to stay there, it didn't pitch forward or backward, it slid rather stabilized.

Mr. FULTON. Have you tried any inertial guidance equipment? Has anybody lent you any to try it?

Dr. KUCHER. In preflight, the airplane is controlled laterally and longitudinally with ailerons and elevator. In a smaller vehicle, the reaction forces would have to come from within the confines of the vehicle, and therefore reaction devices, whether they are air-bleed devices, rockets, or deflectors, would be the method employed.

Correct?

Dr. PERKINS. Something of that nature.

Mr. FULTON. Has the Department of Defense lent you any inertial guidance equipment in trying to work out something on guidance and propulsion?

Dr. KUCHER. May I speak on that? We have a subsidiary company, Aeronutronic Systems, Inc., on the west coast involved in space problems. Their involvement in guidance and control systems is available to us, and we are collaborating with them.

Mr. FULTON. Are you getting adequate cooperation? I am saying from the R and D function of the DOD, and from the President's adviser, Killian, and Dr. York, and NASA, are you getting full cooperation?

Dr. KUCHER. To the degree we have required it, this being an independent operation. We had access to the technical reports, if that is what you refer to, by the recent military contracts. To the degree we called upon them, we have had complete cooperation.

The CHAIRMAN. Thank you very much, sir.

I want to say this, that we prepared a short program for the committee this morning, because we thought before we convened that it would be necessary to be before the House Administration Committee to ask for a request to print more copies of Ten Years in Space. We find it isn't necessary now to be there, so we have completed our program.

We want to thank you again, and the committee will adjourn until tomorrow morning at 10 o'clock.

(Whereupon, at 11:30 a.m., the committee adjourned, to reconvene at 10 a.m., Tuesday, April 14, 1959.)

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
Washington, D.C., Tuesday, April 14, 1959.

The committee met at 10 a.m., in the caucus room, Old House Office Building, Hon. Overton Brooks, chairman, presiding.

The CHAIRMAN. The committee will come to order.

We may be a little slow getting underway this morning due to distractions. On the other hand, we have a great many witnesses to be heard and I think these are very important witnesses, every one of them, and we will call them in the order they are presented as quickly as we can.

We won't be able to meet this afternoon, gentlemen of the committee, because the NASA bill will come up about 1:30, not later than 2 o'clock, I am told. We have got a bill on the floor ourselves, and we hope everybody will be present.

Mr. Bollum, will you step forward, sir? Mr. Bollum is here as a witness for Spacetronics, Inc. Mr. Bollum has a demonstration that he wants to put on in the morning. Would you care to make a statement for the reporter and for the press?

Mr. BOLLUM. The Chief Counsel for this committe and staff members have informed me they are advising the newsreel people that we will put on our demonstration this noon after the committee adjourns, is that right?

Mr. DUCANDER. That is all right.

Mr. BOLLUM. About 12:30. We also will put on a demonstration here in the morning prior to your committee meeting.

The CHAIRMAN. 9:30 in the morning?

Mr. BOLLUM. Yes, sir.

The CHAIRMAN. The demonstration at 12:30, of course, will clash as Congress will be in session then.

Mr. BOLLUM. We think what we have to offer is of enough importance that people ought to see it.

The CHAIRMAN. All right.

Those interested will please take note accordingly. Thank you very much, Mr. Bollum. We will call you tomorrow as a witness.

Now the first witness this morning is Capt. A. B. Metsger, Deputy and Assistant Chief of Naval Research.

Will you have a seat, sir?

Admiral BENNETT. Mr. Chairman, I am Rear Admiral Bennett, the Chief of Naval Research.

The CHAIRMAN. You are Rear Admiral Bennett, Chief of Naval Research, backed by Captain Metsger. Is he here?

Admiral BENNETT. He is not here.

The CHAIRMAN. You have Dr. Boehler, Dr. Gabriel D. Boehler. Is he here?

Admiral BENNETT. He is.

The CHAIRMAN. Do you wish him to come forward now or wait for the questioning?

Admiral BENNETT. No, sir; I believe the only other person to come forward would be Major Wosser.

The CHAIRMAN. Maj. J. L. Wosser, USMC, Scientific Officer, Air Branch, Office of Naval Research.

Major WOSSER. We will come up when the questions are asked.

The CHAIRMAN. All right, Admiral, we are privileged to have you this morning.

You have a statement there. Does the committee have copies of the statement?

Admiral BENNETT. I believe the committee does, sir.

The CHAIRMAN. All right. Mr. Fulton wants to recognize you for the outstanding work which you have done.

Mr. FULTON. Will you please state for the record your technical background as well as your relationship to Admiral Hayward?

Admiral BENNETT. My technical background consists of the basic education of the Naval Academy from which I graduated in 1927. I further undertook postgraduate work in electrical engineering, getting a degree of master of science in electrical engineering at the University of California. I have had as various assignments the Director of Electronics Design for the Navy Department, Assistant Chief of the Bureau of Ships for Electronics, and for the past 3½ years, I have been the Chief of Naval Research.

I am a fellow of the Institute of Radio Engineers, American Acoustical Society, the American Association for the Advancement of Science, and a registered professional engineer. I am the Chief of Naval Research, which is an office established by law, and which is directed to conduct the basic research for the Navy.

Admiral Hayward is the Assistant Chief of Naval Operations for Research and Development, which deals with the requirements primarily, Mr. Fulton.

Mr. FULTON. What is the distinction then between the type of work you do and Admiral Hayward does?

Admiral BENNETT. My office actually directs and conducts the research whereas Admiral Hayward's office does not.

The CHAIRMAN. We have had the pleasure of having Admiral Hayward with us, a distinguished American. We are glad to have you this morning.

Thank you, Mr. Fulton.

Admiral, would you proceed with your statement?

STATEMENT OF REAR ADM. RAWSON BENNETT, CHIEF OF NAVAL RESEARCH, USN

Admiral BENNETT. It is a pleasure to be here this morning, Mr. Chairman.

In the opening remarks by Mr. J. B. Macauley, you have been apprised of the concept of the "ground proximity" vehicle and the coordination of effort being exercised by the Department of Defense in this field. Many claims have been made both here and abroad of possible uses for these machines and some of these applications have been discussed. It is now my purpose to outline the status of the

Navy's investigative efforts in this area and to discuss applications of possible interest to the Navy and Marine Corps.

Preliminary results of initial research efforts have indicated that the ground proximity machine will be able to operate with equal facility over land and water. Therefore, one of the more obvious uses for such a machine is as an amphibious transport or an assault boat. A boat-type bow and water-tight structure with low silhouette and moderate load-lifting capability are design criteria dictated by this mission. Vehicles comparable in size and payload to present amphibious assault craft would be extremely valuable in accelerating the ship-to-shore movement. Traveling 4 or 5 feet over the wave tops at speeds up to 50 m.p.h. and capable of negotiating beaches up to 15 percent slope, the vehicle would present a far less vulnerable target than our present craft and would open the world's tideland and river delta areas as avenues of approach for assault or for peaceful cargo moving.

An application to antisubmarine warfare is visualized using searching and homing devices mounted on a radio-controlled platform. This hunter-killer platform would have to operate at heights only great enough to clear the waves and at speeds only 20 percent higher than the latest atomic submarine. Structurally, the platform should be capable of floating in heavy seas for extended times—then lifting and tracking automatically. Because of its inherent weight-lifting ability, the machine becomes an ideal killer—able to place a bomb or charge directly on the enemy submarine by radio command from the mother ship and then scoot away to safety.

The final configuration I wish to present is the oceangoing transport. The most advanced thinking on these designs has been filtering in from abroad—from Mr. Carl Weiland in Switzerland and Mr. C. S. Cockerell in England. Circular ship platforms 1,000 feet in diameter, capable of speeds up to 150 knots, have been outlined in foreign newspapers and periodicals. Because of their huge size, these machines might operate up to 50 feet above the waves, thus permitting maximum weight-lifting potential and stability.

These are by no means the only applications possible. Our investigators are studying these and many others, and it is certainly possible that some use not even contemplated at this time may be the most worthwhile adaptation of the ground proximity principle.

Having such obvious applications in mind, Navy research personnel from the Bureau of Aeronautics, David Taylor Model Basin, and the Office of Naval Research began monitoring the progress of the AVRO program in Canada in 1954. In mid-1957, following publication of the first U.S. technical report of work conducted in this field by Lewis Laboratory of the, then, NACA, a design study was conducted by the Bureau of Aeronautics Research Division; and combined theoretical and experimental analyses of the phenomenon were begun on a modest funding basis at David Taylor Model Basin.

In September of that year, the Office of Naval Research negotiated a contract with the Aerophysics Co. of Washington to perform more advanced theoretical analyses of the flow processes involved in the operation of annular jets and to attempt to correlate these theories with experimental model test results which were soon to be available from several Government laboratories.

During the past year interest in the potentialities of these ground effect vehicles has increased quite rapidly within the services as a consequence of some of the encouraging test results and theoretical predictions from the early research programs and also because of a few rather dramatic demonstrations by commercial concerns of large flying models and man-carrying machines, such as the exhibition for Government personnel of the Spacetronics, Inc., pressure-leakage vehicle, which was arranged and supported in part by the Office of Naval Research.

Having thus verified the existence of this ground effect and determined its magnitude in hovering in a preliminary way, it then became the task of naval research personnel and their contractors to seek answers to a number of important questions concerning the phenomenon and its employment on an operational vehicle. Typical of such questions are these:

1. What are the effects on performance of a ground-effect machine of changes in its geometry or the method of discharging the jet?
2. What will be the effect on the ground cushion of forward flight by the mechanism?
3. Is operation in either hovering or forward flight over water and waves significantly different from land operation?
4. Are there likely to be problems of stability and control of such a vehicle when operating at reasonable distances from the ground or over particularly rough terrain? If so, what can be done to solve such problems?
5. From known or soon-to-be-discovered influences of various geometric and aerodynamic factors, what compromises or combinations of these factors will produce the optimum vehicle to perform a particular mission?

These and other similar questions are being treated by Navy-sponsored research work which is currently underway and planned for the immediate future. A brief résumé of this program is as follows:

Sponsored by the Bureau of Aeronautics:

1. A $100,000 contract with the Aerodynamics Laboratory of the David Taylor Model Basin to continue theoretical studies and to build and test models in wind tunnels is under consideration.
2. A $47,000 contract with the Gyrodyne Co. to construct and test the static and dynamic characteristics of a man-carrying test-bed hovering machine of about 6-foot diameter is actively in progress.
3. A $50,000 contract with Convair to study the design feasibility of a very large flying vehicle for over-water operation, employing aircraft type structures and possibly incorporating a nuclear power source, has recently been negotiated.

Sponsored by the Bureau of Ships:

1. A $45,000 contract with the David Taylor Model Basin Hydrodynamics Laboratory to construct and test models of catamaran ship type vehicles in a towing tank has been started as a first-phase program.

Sponsored by the Office of Naval Research:

1. A $30,000 contract with the Aerophysics Co. to continue detailed theoretical analyses of the flow processes in the curved jet in both hovering and forward flight and to continue correlations and evaluations of available experimental results is progressing actively.

2. A $21,000 contract with the University of California to test small models over water at varying forward speeds and different simulated wave conditions was recently signed.

3. A $30,000 contract with the State University of Iowa to study the influence on performance of changes in various geometric parameters by small model wind tunnel and water table tests is in progress.

4. A contract for $2,500 with a Swiss designer, Mr. Carl Weiland, to purchase certain theoretical and experimental model tests results of a unique variation of the annular jet principle is in early negotiation stages.

5. A cooperative exchange of unclassified research information in this field is being arranged with ONERA, the French national aeronautics research laboratory.

This diversified program of research has been established to attempt to solve the problems of particular significance in Navy and Marine Corps applications and to supplement the work of other services. Work is proceeding stepwise in a normal and logical fashion toward the ultimate objective of gaining a sufficiently clear understanding of the ground proximity effect and its use on military vehicles so as to enable the services to evaluate accurately the potentials of such machines.

This chart, which Dr. Matthews has here, depicts chronologically the growth of interest in ground proximity machines. Since our first investigative efforts, the Navy has exhibited leadership and maintained an overall cognizance of the work being done. It is our intention to continue to look forward through an objective program which will accomplish the required phases of research and exploratory development leading to the acquisition of an optimum vehicle.

Dr. Matthews, would you like to point out the sequence in time, please?

Dr. MATTHEWS. I will, sir.

Mr. Chairman, gentlemen of the committee, the historical background of work performed on the ground proximity principle as sponsored by the services began with the AVRO contract in late 1954 and early 1955. We have not shown details of this contract because of the classified nature of the work.

The CHAIRMAN. Doctor, let me ask you, what do you mean by annular jet program?

Dr. MATTHEWS. This is the ground proximity vehicle in which the air is discharged from a slot around the periphery of the platform.

The CHAIRMAN. Is that the meaning of the word "annular"?

Dr. MATTHEWS. Yes, sir. The National Advisory Committee for Aeronautics, under the Space Administration, began work by following the AVRO program and performing experimental and theoretical work of their own in mid-1955. This led to publication of a technical note by Dr. von Glahn, at Lewis Laboratories, in April 1957.

This, as Admiral Bennett has pointed out, was the first U.S. Government sponsored work in the field, at least the first of which we were aware. The technical note was published, as I say, early in 1957, and received considerable interest within the Navy Department, who had been following the concept of a ground effect machine as it was exhibited in the AVRO contract since 1955. Mr. Hollenberg of the Bureau of Aeronautics, published a design study in mid-1957. In conversations with the David Taylor Model Basin at that

time, he began a combined theoretical and experimental study at the model basins on models of annular jet vehicles.

Both theory and experiment were performed and have continued since that time at David Taylor Model Basin. In September 1957, the Office of Naval Research, Air Branch, which had been looking at this phenomenon also with interest, believed additional theoretical work should be done, and began a contract with Dr. Boehler of the Aerophysics Co. to perform such detailed theoretical studies. This contract has also continued since 1957.

In late 1958 the Mechanics Branch of the Office of Naval Research began study contracts on experimental tests of vehicles performing primarily over water surfaces: one at the University of California, in Berkeley; the other at the State University of Iowa.

The Bureau of Ships, very late in 1958, and early 1959, has now begun model study programs, experimental primarily, on vehicles designed to perform particularly over water. These are the catamaran-type vehicles Admiral Bennett touched on earlier. In the way of man-carrying vehicles, the Bureau of Aeronautics as a result of the receipt of a number of unsolicited proposals, chose to negotiate a contract with the Gyrodyne Corp. in Long Island to build a man-carrying vehicle for dynamic testing purposes primarily.

This vehicle was, I am sorry to say, erroneously reported to be 15 feet in diameter. It is actually 6 feet in diameter. This is now under construction. It is estimated its first test flight will be in August of this year.

Very recently a contract was signed with Convair for the design feasibility study of a very large oceangoing machine. This contract is primarily interested in the structure of the machine, the probable distribution of weights and payloads, the possible propulsion systems, and the potential application of nuclear powerplants to such devices.

The Army has also been heavily interested in the field; I will not go into details, since I know they wish to present their own program. The two original contracts of which we were aware, in addition, of course, to the AVRO contract in which they have invested heavily, were the contract with the National Research Associates, now of Silver Spring, Md., and the Army Transportation Research and Engineering Command contract which began late last year with Princeton University.

In the way of foreign work, Mr. C. S. Cockrell of England had been working on this phenomenon privately and rather quietly for quite some time, beginning, we think, in 1955. The Ministry of Supply as a result of their white paper on man-carrying aircraft, dropped the support of this contract in England which was being performed at the Saunders-Roe Aircraft Co., and the work was taken over by the National Research and Development Council which is the British equivalent to our National Inventors Council, with the objective of demonstrating commercial possibilities for such a vehicle.

In 1957, a representative of Carl Weiland from Zurich, Switzerland, who had invented a similar annular jet machine with what is now known as a labyrinth seal, contacted the naval attaché's office in Paris. The interest in this vehicle then spread to the Office of Naval Reserve branch office in London, and finally to our own office here in Washington, and at the moment we are attempting to negotiate

through the Swiss Government with Mr. Weiland to obtain test results of this particular sealing mechanism. Thank you.

Admiral BENNETT. Thank you, Dr. Matthews.

The CHAIRMAN. Thank you, Doctor. Admiral, we appreciate your fine statement, sir. We appreciate your being present, too.

I would like to ask you a few questions. Would you care now to have Captain Metsger and Dr. Matthews?

Admiral BENNETT. Dr. Matthews and Major Wosser will step forward now, sir.

The CHAIRMAN. These inventions to which you refer, do you classify them all as ground proximity machines?

Admiral BENNETT. Yes, sir.

The CHAIRMAN. Would you classify them all as naval machines?

Admiral BENNETT. The ones we are interested in are for naval applications.

The CHAIRMAN. Some of them are amphibious, aren't they?

Admiral BENNETT. Yes.

The CHAIRMAN. Some are not?

Admiral BENNETT. It is sometimes forgotten, sir, the Marines are part of the Navy, although sometimes they regret it, I understand.

The CHAIRMAN. We are not overlooking that, after 20 years legislative history, I am not overlooking that.

Would you classify these as weapons, or potential weapons?

Admiral BENNETT. No, sir. They are more in the nature of vehicles or carriers, Mr. Chairman.

The CHAIRMAN. They are carriers?

Admiral BENNETT. Yes, sir.

The CHAIRMAN. Rather than weapons?

Admiral BENNETT. Yes, sir.

The CHAIRMAN. If they are developed—I wish you would elaborate on the potential possibilities of the military use of these carriers.

Admiral BENNETT. I think perhaps it might be informative to the committee, Mr. Chairman, if Dr. Matthews would show you some sketches at this point.

The CHAIRMAN. Off the record here.

(Discussion off the record.)

The CHAIRMAN. On the record.

Can all of the members see that picture there? If you can't, if you will come forward here around the chairman or to the left of the committee, there are plenty of seats. All right, Doctor.

Dr. MATTHEWS. Mr. Chairman, this is an artist's conception of what the full-scale Gyrodyne machine will look like. This does not illustrate a particular application, but rather gives an idea of the size and probable configuration of this test vehicle.

The next sketch——

The CHAIRMAN. Well, now, wait, before you go on that, is that an amphibious vehicle?

Dr. MATTHEWS. This could be an amphibious vehicle, yes, sir. It is not designed for a particular military mission, since it is a test model.

The CHAIRMAN. How many is it designed to carry?

Dr. MATTHEWS. One man.

The CHAIRMAN. And his equipment?

Dr. MATTHEWS. And his personal equipment.

The next sketch is the antisubmarine warfare application which Admiral Bennett described earlier. The drawing here is slightly in error in that the machine is shown operating higher above the waves than it would be anticipated actually to be able to perform.

The CHAIRMAN. How high is it shown there?

Dr. MATTHEWS. On the basis of average sea state, with the wave height of perhaps 6 feet, this is shown operating at about 10 feet above the mean of the waves.

The CHAIRMAN. That wouldn't operate in very rough weather, would it? You can't operate more than 10 feet above the waves.

Dr. MATTHEWS. This is one of the questions we will have to answer in research and development problems, sir. We don't know enough to say what the rough weather possibilities of such a machine would be right now.

The CHAIRMAN. You have to develop that?

Dr. MATTHEWS. Yes, sir.

The CHAIRMAN. Just proceed, sir.

Admiral BENNETT. Thank you, Dr. Matthews.

These, I think, are among possible dreams, if one may say that ugly word, which illustrate some of the developments which might occur.

I would like to emphasize, Mr. Chairman, we are in the research and development phase of these vehicles, and no one knows quite what to expect from them.

The CHAIRMAN. But you have pretty well established the phenomenon of ground proximity?

Admiral BENNETT. Yes, sir.

The CHAIRMAN. The feasibility is established, and you know pretty well that out of this research work something can be developed, whether it will be of potential use to the Navy or not is now doubtful, isn't it?

Admiral BENNETT. Well, it is uncertain, sir.

The CHAIRMAN. It is uncertain, yes, but as to the development, you pretty well established its possibilities there.

Admiral BENNETT. Yes, sir.

The CHAIRMAN. Mr. Fulton.

Mr. FULTON. We are glad to have you here. I believe you have given us something to think about in the future on this particular type of approach.

The question comes up, are you making your research base broad enough by simply picking one company on each of these proposals?

Why don't you do it as a pyramid and have a number of companies look into the basics and then as you go along into combined companies, and the ones who do not have good ideas leave them off until you finally get up to where you have two or three companies working on applied operation?

I have been disagreeing right straight through on this method of picking one company and then saying, put the man in space, or you handle man on a ground proximity operation.

I believe that you would be very well advised if you would come up to this committee with some plans for a broader participation of the research and development facilities, both applied and pure research, in industry and in the universities. So if I have any criticism this morning, it seems to be they are picking somebody like a bishop

or somebody in the king row, and saying, "You are the fellow, now do it."

I think you would get many ideas that have no value, but you also would be scanning the field and have a good many more people looking at it.

The second thing is this: Why is it always necessary to have an annular or a circular type of effect? Why don't you have it in, say, an elliptical form, or why couldn't it be square, rectangular or triangular? What is the reason for it always being annular?

Admiral BENNETT. Dr. Matthews.

Dr. MATTHEWS. Mr. Fulton, the platform must not necessarily be circular, and hence the jet annular.

Mr. FULTON. Wouldn't it help you if you would go into some tests on load distribution?

The CHAIRMAN. Would you put that microphone nearer you, Doctor?

Dr. MATTHEWS. Yes, sir, it would; and the contract with the State University of Iowa, as well as the contract which the Army has with National Research Associates, is directed toward an investigation of platforms other than circular, also toward the effects of very thick jets, which means departing somewhat from the annular configuration.

Mr. FULTON. Have you tried, as we do on ordinary missiles, having jet streams that are operable by a person, or you can have instantaneous correction based on either ground conditions, or on surface conditions, or pressures, or forces?

Dr. MATTHEWS. Sir, we have not tried that—that is, the Navy Department has not, to my knowledge, performed investigations in this field; but the Army has. And we are cognizant of and trying to coordinate with their efforts.

Mr. FULTON. What kind of coordination system do you have set up between the military agencies working on these things, both within this country and for example, with Britain and with France on her Research ONERA?

Dr. MATTHEWS. Within this country, Mr. Fulton, the coordination, cooperation, and dissemination of information has been between the individuals sponsoring the contracts and those administering or overseeing the contracts in the various services and in the Department of Defense, through Mr. Macauley's office. There has been a great deal of personal communication between those parties interested to find out what work is being sponsored by the other services, and what work is done in various laboratories, including those of the NASA.

With regard to work performed in foreign countries, we depend primarily on intelligence information from our naval attachés' offices and the ONR office in London, as well as the Army's Research and Development Office in Frankfurt, Germany.

Our contacts with ONERA in France are both personal and official, with individuals with whom we have become acquainted.

Mr. FULTON. When Congress finished last year, the reason I say this——

The CHAIRMAN. Mr. Fulton, may I interrupt? Some of the members at the other end of the committee indicate they can't hear your questions.

Mr. FULTON. I will talk louder.

The CHAIRMAN. Yes.

Mr. FULTON. The reason I bring this up is when Congress finished last year, I went over to the University of Manchester, and likewise went to Cambridge University on radio-telescope work. I was struck by the fact we were not giving these people the opportunity to use their facilities of a scientific nature full time, and that they were limping along because they didn't have the money. The free world had some scientific facilities going to waste part time.

I note from the admiral's statement that Mr. Carl Weiland in Switzerland, and Mr. C. S. Cockrell in England are working on these programs and that you comment very adequately and I think tragically, on how advance thinking on these designs has been filtering in from abroad. That doesn't sound good to me. I think the Navy should be using scientific brains on this wherever they are, and there should be much more of a correlation, and information supply, than just a filtering in from abroad.

Admiral BENNETT. Mr. Fulton, you will have to appreciate the fact that as Dr. Matthews mentioned, some of these developments abroad are of a commercial nature. This means the amount of information we are going to obtain at a particular time is rather limited.

Mr. FULTON. Making money doesn't enter into scientific brains. I think you should go after the commercial sources, as well as the military and Government sources generally. I don't think that there is a limit on anybody's scientific knowledge.

Admiral BENNETT. I don't believe so either, sir, but you must remember we have a limited amount of money, and we have to do the best we can with it.

Mr. FULTON. That is my next question. Do you have enough money to do a good job on this type of research and development, both pure and applied? If you don't, tell us how much it is, and what you want, and this committee may help you get it. I think there are some fellows here who would be very pleased to help you get it.

What do you need?

Admiral BENNETT. At this particular point in time, Mr. Fulton, I would say we are adequately funded. We need more information before we can spend any additional money to advantage.

Mr. FULTON. Suppose you adopted the method that I recommended, the pyramided type of scientific research instead of the one you are now employing, could you use more money?

Admiral BENNETT. Not on this one, sir. We could use it on something else if we had the money.

Mr. FULTON. It is peculiar, they always come up here and feel they could do more if they had more money, then we say we will give it to you, and they are always afraid to come out and say what it is.

Is there anybody in the Navy who can tell us what kind of extra money you need to put a really advance program on in the research and development, on this kind of propulsion?

Admiral BENNETT. Yes, sir, I would be glad to tell you if I thought we needed it, on this particular area.

Mr. FULTON. May I ask you to put in the record rather than do it here, what your requests were that were turned down either by higher echelons of naval authority, the Secretary, the Office of Research and Development in the Department of Defense, or the Joint Chiefs,

Bureau of the Budget, or Dr. Killian's office. If you will put that in the record, I would appreciate it.

Admiral BENNETT. I would be pleased to.

(The information requested is as follows:)

NAVY STATEMENT ON UNFUNDED REQUIREMENTS

The Navy's budget request submitted to the Secretary of Defense included approximately $150 million worth of research and development projects that were not included in the budget submitted to the Congress. It is difficult to determine the exact amount that was included in unfunded portions of the budget for ground proximity projects. However, a minimum of $275,000 in direct support of this field can be identified. It is estimated that an equal amount of support would be found in related projects of broader scope.

Mr. FULTON. I would like your original recommendations and then where they were cut.

Admiral BENNETT. Yes, sir.

Mr. FULTON. Then the question comes up to me, if this could be used as well on sea as on land, it wouldn't have to be used on just level land, or a level surface, would it?

Dr. MATTHEWS. Mr. Fulton, this is one of the real problems that we are investigating and hope to have answers to, as to what——

Mr. FULTON. Yesterday it was stated it had to be level and I disagreed with it. You say it is a problem that should be studied, because to me, if you can have a different type of jet in velocity and volume on various portions of this platform, you really could do mountain climbing with it, couldn't you?

Dr. MATTHEWS. It is very possible, sir. The stability of the device at an angle is one of the problems not yet clearly answered.

Mr. FULTON. If you put it outside a building or inside a building, you could supersede every elevator in the country, couldn't you?

Dr. MATTHEWS. To limited heights.

Mr. FULTON. You could have this thing climb the steps, couldn't you?

Dr. MATTHEWS. Yes, sir, if the steps had very low risers.

Mr. FULTON. The building of the future, you might have a circular stair going up with this thing climbing, isn't that possible?

Dr. MATTHEWS. It may be possible.

The CHAIRMAN. Do you think you could use that over in Tibet today if you had it available on those mountains over there?

Mr. FULTON. That is a very good point.

Admiral BENNETT. Having seen some of those mountains, I doubt we could use it today, sir.

The CHAIRMAN. In Tibet?

Admiral BENNETT. Yes, sir.

Mr. FULTON. Yes, but you could use them up those tortuous valleys, I have seen them, too.

The valleys have generally level floors or moderate slopes.

The CHAIRMAN. What does the admiral have to say on that?

Admiral BENNETT. Obviously, as Dr. Matthews has said, we need to know a great deal more about it before we are sure of anything except level ground. This is what we are trying to find out.

Mr. FULTON. I think the chairman has a good point. I think it should be investigated as to the use of this type of a vehicle in mountainous, hilly areas.

Now another thing is, then, if it can be used on water, you are thinking of the sea. Of course, I come from the city of Pittsburgh, and we have three rivers. Now, assume this could be used on water, to lift things a short distance. We have a series of locks all up and down the Monongahela, the Allegheny, the Ohio, and the Mississippi Rivers. Maybe if you would put some investigation on this, you would find you are outmoding and making obsolescent every one of the locks on our rivers.

Why, then, shouldn't we have the locks only 2 or 3 feet above the water surface, and when the boats and the tows come to the dams, rather than go through the expensive process of locks, simply skip them over on the way down, or skip them over on the way back? What do you think of that, Doctor?

I believe you have been around Pittsburgh and Johnstown, haven't you?

Dr. MATTHEWS. Yes, sir; I have.

Mr. FULTON. What do you think of that?

Dr. MATTHEWS. I think that if we can demonstrate the capability for negotiating step terrain and for actually performing a jump-type maneuver, with both hovering and forward flight involved, this would be a very interesting application.

Mr. FULTON. As a matter of fact, you wouldn't have to have the particular facility on the boat. It could be on the dam, couldn't it, so when the boat came to it, it floated on air, went over the dam, and went back into the water?

Dr. MATTHEWS. That would be very difficult, sir, because the air would be dissipated very rapidly, coming out of the dam, rather than out of the boat. You see, the jet emanating from the boat, itself, would dissipate less energy than having it spread over the dam, under the surface of the boat.

Mr. FULTON. The boat might have something jetted out ahead of it, you see, some sort of an operation that the boat went on.

Dr. MATTHEWS. It might.

Mr. FULTON. One other thing. If it can be used to go up, why can't it be used to go down? For example, why couldn't you reverse this and go to tremendous depths in the ocean? Why couldn't you use it for a diving apparatus, if you can use it for a flotation apparatus?

Admiral BENNETT. I don't believe it would be suitable for a diving apparatus, Mr. Fulton, because the entire effect of this vehicle depends on the disparity of pressure between the vehicle and a surface. Once under the water, there would be no surface, in other words, no clearance possible. The water would close in around it.

Mr. FULTON. You might have a baffle. Have you ever tried that, that would jet out against the baffle and then it has to escape, and that causes force.

Admiral BENNETT. I believe this would be a remote possibility, sir.

Mr. FULTON. May I just finish with this?

We would recommend to you that you come up to us with a much broader base program of other companies that might be engaged in this particular type of development, and I would ask the Navy to put in the record at this point the list of possible companies that could be used on this type of research and development, both pure and applied, and likewise the number of people and their names and addresses and

what the proposals were that have been refused to outside companies wanting to do work in this particular field. That is all.

(The information requested is as follows:)

CONTRACTORS

All of the aircraft, automobile, or small boat manufacturers as well as most of the universities and privately endowed research and development laboratories are possible organizations that could be used on this type of research and development, both basic and applied. However, the following list of contractors has been compiled from records available to the Office of Naval Research of those contractors who have indicated interest and capability in this type of research and development through contacts with the Bureau of Aeronautics, the Bureau of Ships and the Office of Naval Research.

ORGANIZATION	GROUND EFFECT RESEARCH & DEVELOPMENT PERSONNEL
Aerophysics Co., 17 Dupont Circle, Washington, D.C. (four employees).	Chief Investigator, Dr. Gabriel D. Boehler (three full-time, one part-time employees).
American Research & Manufacturing Corp., Rockville, Md. (65 employees).	Chief Investigator, Mr. H. Goda (number of employees unknown).
Ames Research Center, NASA, Moffett Field, Calif. (1,434 employees).	Chief Investigator, C. W. Harper (approximately six employees available for full-time testing).
AVRO Aircraft, Ltd., Malton, Ontario.	Chief Investigator, J. C. M. Frost (approximately 6 engineers, 30 shop employees currently active).
BEE Aviation Associates, Inc., San Diego, Calif. (approximately eight employees).	Representative, K. S. Coward (approximately six part-time engineers and technicians).
Bertelsen Manufacturing Co., Neponset, Ill. (two employees)	Designer, Dr. W. R. Bertelsen (approximately two part-time employees).
Convair Division, General Dynamics Corp., San Diego, Calif. (23,794 employees).	Representative, F. Fogelman (approximately 10 persons now employed on research studies in this field).
David Taylor Model Basin, Carderock, Md. (1,293 civilian employees and 41 Navy personnel).	Chief Investigators, H. Chaplin, Aerodynamics Laboratory; A. Hirsh Hydrodynamics Laboratory (approximately seven full-time research and technical employees on current studies).
F. A. Dobson, 8205 Calmosa Ave., Whittier, Calif. (one employee).	Mr. F. A. Dobson, single investigator.
Eastern Research Group, 120 Wall Street, New York, N.Y. (approximately 15 employees).	Chief Investigator, Dr. L. Meyerhoff (approximately four theoretical analysts available for this field).
Grumman Aircraft Corp., Research Department, Bethphage, Long Island, N.Y. (14,431 employees).	Chief Investigator, Dr. K. Centers (approximately five employees currently engaged in research).
Gyrodyne Co. of America, Inc., St. James, Long Island, N.Y. (100 employees).	Chief Engineer, E. Strong; test pilot, J. Rouse (approximately five full-time personnel involved in current program).
Hiller Aircraft Corp., Advanced Research Division, Willow Road, Palo Alto, Calif. (925 employees).	Chief Investigator, E. R. Sargent (approximately six persons in related aerodynamics research).
Langley Research Center, NASA, Langley Air Force Base, Va. (3,587 employees).	Chief Investigator, R. Kuhn (approximately five persons in current research).
Lockheed Aircraft Corp., Georgia Division, Thermodynamics Group, Marietta, Ga. (14,552 employees).	Chief Investigator, Dr. J. F. Sutton (approximately 10 people currently in related aerodynamics programs).
The Martin Co., Preliminary Design Section, Baltimore, Md. (18,000 employees).	Chief Investigator, M. Schwartzberg, single engineer currently performing performance analyses.

ORGANIZATION—continued	GROUND EFFECT RESEARCH & DEVELOPMENT PERSONNEL—continued
National Research Associates, 9592 Baltimore Ave., College Park, Md. (51 employees).	Chief Investigators, W. Alper and M. Beardsley (approximately 18 in current work).
Naval Research Laboratory, Washington, D.C. (3,017 civilian and 94 Navy personnel).	Chief Investigator, C. D. Porter, (approximately three engineers now involved in research testing).
North American Aviation, Columbus Division, Columbus, Ohio (10,500 employees).	(Number of persons in research in this area unknown.)
Office Nationale Etude et Recherche Aeronatique, Chatillon-sous Bagneaux, Seine, Paris, France (2,000 employees).	Chief Investigator, P. Poisson-Quinton (approximately four persons currently involved).
Princeton University Aeronautical Engineering Department, Princeton, N.J. (1,500 employees).	Chief Investigators, Prof. C. D. Perkins and T. Sweeney (approximately four persons in current work).
Saunders-Roe, Ltd. Cowes, Isle of Wight, England (number of employees unknown).	Designer, C. S. Cockrell (number of persons on current project unknown).
Spacetronics, Inc., 4932 St. Elmo Ave., Bethesda, Md. (three employees).	Chief Investigators, C. W. Bollum and W. Crowley (three persons currently engaged in this field).
The Martin Co., Advanced Systems Requirements, Orlando, Fla. (6,400 employees).	Representative, L. E. Carroll (approximately eight persons currently active).
State University of Iowa, Ames, Iowa.	Chief Investigator, Prof. Landweber, (approximately three persons engaged part time on current project).
Robert Taggart, Inc., 525 Woodland Dr., Fairfax, Va. (two employees).	Chief Engineer, R. Taggart, (two employees currently involved).
University of California, Institute of Engineering Research, Berkeley, Calif.	Chief Investigators, Prof. J. V. Wehausen and Prof. J. W. Johnson (approximately four people on current program part time).
University of Maryland, Aeronautical Engineering Department, College Park, Md.	Chief Investigator, Prof. Shen (approximately two persons part time) expected to participate in research effort).
Vehicle Research Corp., 587 Drexel Place, Pasadena, Calif. (five employees).	Chief Investigators, Dr. S. Rethorst and Prof. W. Royce (four persons employed in related aerodynamics analysis).
Carl Weiland, Zurich, Switzerland (one person).	Single investigator is Mr. Carl Weiland.

PROPOSALS

The following is a list of proposals which has been rejected. This list is current as of April 14, 1959.

Proposing organization	Receiving agency	Date of submission	Description
BEE Aviation Associates	BuAer	April 1958	Research vehicle construction and test.
Hiller Aircraft Corp	ONR	Sept. 15, 1958	Experimental study of water proximity surface disturbances.
National Research Associates	BuAer	May 1958	Research vehicle construction and test.
North American Aviation	BuAer	June 1958	Research vehicle construction and test.

The CHAIRMAN. Thank you, Mr. Fulton.
Admiral BENNETT. Yes.

The CHAIRMAN. Are there any questions?

Mr. SISK. No questions.

The CHAIRMAN. No questions down there?

Thank you very much, Admiral.

I would like to ask you a question. You refer to, in the course of your statement, the developments overseas in Europe of large platforms, very large, 1,000 feet, you say.

Do you have anything more definite than just simply rumor or a hazy type of information?

Admiral BENNETT. I believe these are ideas at the present stage for which some blueprints or some material of that type exists.

The CHAIRMAN. Nothing has been developed tangible?

Admiral BENNETT. Not so far as I know, not tangible.

The CHAIRMAN. Thank you very much.

Mr. FULTON. Just a minute. Would you please put in the record at this point for us, at a later time, the newly reorganized research and development, both pure and applied scientific elements in the Navy at the present time? I would like to have that right up to date, please.

Admiral BENNETT. Mr. Fulton, this would not be any change, because at the present time there is no new arrangement.

Mr. FULTON. I understood that it had been reorganized last year sometime with some changes being made.

Admiral BENNETT. I believe what you are referring to is the report of the board which has not yet been approved by the Secretary, sir.

Mr. FULTON. Thank you, Admiral. Thank you gentlemen.

STATEMENT OF BRIG. GEN. F. H. BRITTON, DIRECTOR OF DEVELOPMENTS, OFFICE, CHIEF OF RESEARCH AND DEVELOPMENT, U.S. ARMY

The CHAIRMAN. General, will you have a seat, sir? We are happy to have you. We find you are supported by Lt. Col. T. E. Haynes, Air Mobility Division, OCRD; Maj. J. L. Pierce, Air Mobility Division, OCRD; Maj. Jack E. Downhill, Office Deputy Director of Development, USAF.

Would you wish them to come forward and sit with you, sir, or do you wish that they wait until the questions are propounded?

General BRITTON. I prefer, sir, that they wait, because I am going to use two of these officers to help me with my pictures.

The CHAIRMAN. Do you have a prepared statement, sir?

General BRITTON. I do, sir.

The CHAIRMAN. General, if you will proceed with your statement, we would appreciate it very much.

General BRITTON. Yes, sir. Mr. Chairman, and gentlemen of the committee: I am Director of Developments, Office of Chief of Research and Development, U.S. Army.

It is a pleasure to have this opportunity to appear before your committee to discuss ground-cushion effect and its application to military vehicles of the future.

Before I discuss the active projects that we have in this field, I believe it is most appropriate to give you some background and the

reasons why the Army has such a vital interest in the application of this phenomenon. Military success depends upon firepower, communications, and mobility. You are thoroughly familiar with the tremendous advances that have been made in firepower available to military forces since World War II. Similarly, communications have been vitally improved. For our Army to exploit these advances both offensively and defensively, mobility must keep pace, but improvements have lagged behind the achievements in the two other fields. The American Army has made and is making definite advances in ground mobility, but something more is required for the future—particularly in limited war. We hope to provide much of the mobility required in the future by the integration of air vehicles into combat and combat support units.

Originally, Army aviation was used principally for observation, command, and liaison-type missions. Since World War II, its capabilities have been exploited and expanded for additional missions such as the movement of troops in the combat zone, the movement of critical supplies, and battlefield casualty evacuation.

We are now moving toward the use of aerial vehicles as actual replacements for ground vehicles in certain combat units. First to be considered are those units fulfilling the traditional cavalry roles of reconnaissance, screening, pursuit, and other such tasks requiring "hypermobility" in comparison with the rest of the Army.

For centuries the armies of the world have used woods, hills, and other terrain features to provide cover and concealment. On the other hand, these very same features have seriously limited these armies in their mobility and maneuverability. With air vehicles designed for our purpose, we expect to develop certain air mobile units which will continue to make use of terrain features for cover and concealment, yet free these same units from obstacles of terrain.

It takes little imagination to see the advantage this could give us especially in such actions as delaying action, reconnaissance in force, pursuit or in the opening days of limited war. We actually have such a unit in being utilizing currently available equipment.

To illustrate this usage, I would like to show you a short film which will show some of the techniques I have been talking about. We recognize that the helicopter falls far short of many of the requirements that aerial vehicles must meet in this air mobile role.

(Film—Air Cavalry film shown.)

As you see, air vehicles for this work require the ability to operate close to the ground but with the altitude capability necessary to cross terrain barriers and trees. The helicopter is not completely adequate because the exposed rotor systems inhibit freedom of movement in confined areas. It is inherently limited in speed and difficult to operate at night close to the ground. In addition, it is very limited in range and is difficult to move strategically even in large Air Force type strategic carriers. Finally, it makes an unstable platform for weapons.

Because of these limitations, the Army has been exerting considerable effort over the past 3 years to develop what have been called minimum ground-pressure vehicles. I should like to point out that to fulfill the missions I have been talking about, it is essential that such vehicles be able both to hover, or move in ground effect, and to fly

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at altitudes of at least 50 to 100 feet, so as to be able to cross average woods, river banks, ravines, fences, and hedges out of the ground effect.

We started our work in search of a vehicle that could do these things shortly after the Korean war with the Hiller flying platform which is shown in this film.

(Film—Hiller platform film shown.)

I would like to point out that while this project has been completed and though it was not suitable for our use, it was most valuable. It did illustrate the possibility of using the ducted-fan principle in larger vehicles suitable for Army use. An example of this application is a much-publicized flying vehicle developed for the Army by the Piasecki Aircraft Corp. shown in this film.

(Film—Piasecki Test Bed film shown.)

You should realize that this is only a research vehicle and is not intended as a final prototype. Based on the test results that we obtain from this project it may be possible to design a suitable vehicle for field use. We have two similar projects that also employ the ducted fan for propulsion, one being developed by Aero Physics—and this is the Aero Physics of California, a subsidiary of Curtiss-Wright—and one by the Chrysler Motor Corp. All three of these utilize different techniques for stability and control.

Another approach to taking advantage of ground-cushion effect is a project that we have with National Research Associates, Inc. Though only a feasibility study, the results may have application for certain types of vehicles. This project utilized ground cushion to lift a vehicle a foot or two off the ground as it traverses "good" terrain. It is not a flying machine in the sense of our other projects and thus would be limited to use over terrain suitable for use by ground vehicles, although with greater flexibility. I will not go into the details on this project because it is my understanding that personnel from the National Research Associates will appear before this committee to give a detailed explanation of their work.

We have not confined our efforts merely to the development of these research aircraft but have considered other aspects of this new approach; for example, we have developed a parachute which can safely land an occupant of one of these vehicles if he has engine or other type of failure. This quick acting parachute will safely put a man on the ground from altitudes of a few feet.

Finally, I would like to make reference to a joint Army-Air Force sponsored program to develop a VTOL research vehicle with AVRO Aircraft Limited of Canada which makes use of the ground-cushion phenomenon. This research vehicle, known as the Avrocar, appears to offer a great potential to the U.S. Army for increasing its mobility in the combat area.

The Avrocar will have a hovering capability as do other ground-effect vehicles, but it will have a much higher performance outside the ground cushion than the ducted-fan research vehicles which I have previously mentioned. This development is now in the advanced stages and we expect to start ground testing sometime in the near future. Since the details of this project are classified, we have a classified briefing which we are prepared to present at the committee's convenience if they so desire.

Although this description has been very brief, I hope it does give you a feel for the work that the Army is doing to exploit the ground-cushion phenomenon and how we intend to use it. It has been a pleasure for me to appear before this committee and I will be happy to answer any questions that you may have.

The CHAIRMAN. Thank you very much, General. In reference to the classified briefing, I would suggest if it is satisfactory with you that, at the conclusion of the testimony, before the committee, we could then hear your classified briefing on that point. We have a lot of witnesses, and we wouldn't want to hold them during the classified briefing, if that could be avoided.

I want to ask you in reference to your statement about this: You state that we actually have such a unit in-being utilizing currently available equipments.

General BRITTON. You refer to the reconnaissance type unit I depicted in the picture. In fact, the picture was made of some of the unit at Fort Rucker.

The CHAIRMAN. Is that using a helicopter?

General BRITTON. It is, sir. We have to find out the operational problems and tactical concepts. This helps us determine our actual requirements in any final vehicle.

The CHAIRMAN. What is new in reference to this use of the helicopter? Hasn't the helicopter been used as a weapon for some time?

General BRITTON. That is correct, sir. It is more a matter of employment, flying in the nap of the earth, and using cover more carefully, including the simplified weapons mounting on the helicopter.

The CHAIRMAN. So there are new uses——

General BRITTON. For an old piece of equipment; that is right.

But we are trying to depict where we are going—as we get the better equipment to do a job in this field.

The CHAIRMAN. General Britton, do you anticipate or do you envision any wide scale use of the equipment, the type to which you referred this morning in your statement?

General BRITTON. I would say, sir, that we anticipate a fairly high degree of use, but not a complete replacement. I certainly believe we are going to have our present equipment with us for many years to come. These will be supplementary to assist combat organizations such as weapons carriers for infantry weapons in their ground role.

The CHAIRMAN. This is just equipment for the infantry?

General BRITTON. Yes. And for the reconnaissance units and even possibly for reconnaissance teams of the artillery and various applications.

The CHAIRMAN. When do you envision the use of that by the infantry?

General BRITTON. There, sir, it would be primarily as their weapon carriers, and helping them in their mobility work. I would rather not predict, because we are still in the very early stages of determining the characteristics of what will be the more optimum vehicles.

The CHAIRMAN. Is it a long term, medium term, or long range?

General BRITTON. I would anticipate we will start getting these in, in 1965.

The CHAIRMAN. 1965?

General BRITTON. Yes, sir. That is an estimate on my part, sir.

The CHAIRMAN. Any questions?

Mr. HECHLER. I have a brief question, General Britton. What is the principle behind the operation of the fast-opening parachute? Is that a ground-cushion principle, too?

General BRITTON. No, not entirely. This is basically a parachute. Our first model we strapped on the man's back, but later we found it is best to strap them to the vehicle. By pyrotechniques, or by explosive charge, we shoot the parachute package up in the air behind the man. With a small explosive charge we pop it open, then it is a normal 24-foot parachute to cushion the man's fall.

Mr. DADDARIO. General, do you contemplate that all the drivers of these vehicles will get flight pay?

General BRITTON. I have no answer to your question, sir.

The CHAIRMAN. Maybe they will get a special infantryman's badge?

General BRITTON. I think if we can get these machines simple enough, of the type we are talking about today, that it does not require extensive pilot training. Of course, it would then be much better for the Army, in that we could have a much wider use.

The CHAIRMAN. Mr. Anfuso.

Mr. ANFUSO. General, what altitude can you get on the Hiller platform?

General BRITTON. The Hiller platform has completed its flight test program. We are still analyzing the results. As a stunt, the test pilot took it up over 50 feet for a very short time. Most flights were made at an altitude of 10 feet or less.

It is not a high flying machine at all.

Mr. ANFUSO. What do you call the other one, the Piasecki Test Bed?

General BRITTON. That is the one you saw the picture of, sir, of the two ducted fans.

Mr. ANFUSO. You say Chrysler was experimenting on that?

General BRITTON. Chrysler has one that is almost finished but has not yet been flown. It uses two ducted fans, but different principles of control. It is quite similar in appearance to the Piasecki one. The one that the Aero Physics people in California are building uses four fans, and we control it by differential fan speed.

Mr. ANFUSO. When do you expect to get to the production stage on any of these?

General BRITTON. Sir, I doubt that any one of these three will go into production as they stand, because we are studying them to find out what we want and can get. In fact, this is very similar to what Mr. Fulton recommended of a broad base. The work of our tactical unit, actually using helicopters, and our research vehicle projects will be used to finalize military characteristics that we desire. We will have a better feel for the state of the art as to what can be built in the near time frame from this, and we will then set our requirements and go into development, for which, of course, there will be a competition.

Mr. ANFUSO. Do you have any prediction?

General BRITTON. We expect to finish the work on these ducted vehicles in 1960—that is, all the testing that has to be done. Based on the information obtained, we will make our final decision at that time.

Mr. ANFUSO. It will take at least 2 or 3 years more after that?

General BRITTON. I would say so, based on normal airframe development in that type of work, and seeing that this is a new area, very definitely.

Mr. ANFUSO. Can you give any idea now as to cost, of a Hiller Platform, for example, and the test bed?

General BRITTON. Sir, the only cost factors we have on these are the actual costs of building these research machines. They are practically handmade. I would be hard pressed to give you a production estimate right now, sir. I doubt that I could do it properly.

Mr. ANFUSO. That hasn't even been discussed, I gather?

General BRITTON. No, sir; it is a point we will come to later on. It will consider number needed, mission, even what kind of powerplant we are going to put into it. It is too early to predict.

Mr. ANFUSO. It certainly is a great thing to look forward to. I think it will help traffic, not only militarywise; I think it is going to help civilian traffic.

General BRITTON. I don't know whether traffic will be worse when they are off the ground at different levels or not.

The CHAIRMAN. It may be worse. Mr. Wolf?

Mr. WOLF. General, it seems to me that this would be extremely vulnerable to attack from the enemy. What do you do? You are like a sitting duck riding around in this thing.

General BRITTON. Sir, this is not an assault vehicle in the sense of a tank. We would employ this much the same way we do our thin-skin weapons carriers today. You fire from these vehicles, where you can get ground cover and only expose yourself to firing and get back out. This is one of the problems. We recognize in the reconnaissance role there are certain vulnerabilities, just as there are certain gambles.

We are making studies of vulnerabilities. We have some work going on today, using present types of equipment and trying to employ them in the manner that we think the future machines would operate. This is to test out the time of reaction of the men on the ground. This is work that is going on in our Combat Developments Experimental Center in California today, to determine some of these vulnerability factors.

Mr. WOLF. These pictures of the helicopters, with rocket-launching platforms. This is experimental?

General BRITTON. Yes; and its purpose is to determine how we would employ them to give us a better feel of the type of equipment and what characteristics are most important. The helicopter is not well suited for the mission. The small observation helicopter when it is working close to the ground, as you saw them with the machine-guns, can do a fairly good job. When you get to the larger ones that are not quite as agile, they are less capable of using ground and ground cover.

The CHAIRMAN. Any further questions? If not, we thank you very much, General, for coming here and giving us the benefit of your testimony. We appreciate that very much.

Would it be inconvenient to you if we did have a classified briefing at the end of this hearing?

General BRITTON. At any time, sir.

The CHAIRMAN. It will probably be tomorrow before we get to it.

General BRITTON. Yes, sir.

The CHAIRMAN. Thank you very much.

Now, Mr. Bollum of Spacetronics has been anxious to present his testimony to this committee at an early time. Is he here? Would you care to make your statement now?

Mr. BOLLUM. It would take a few minutes to set up our program.

The CHAIRMAN. We could call on the National Research Associates while you set up. Couldn't we do that? Is the National Research Associates witness here?

Mr. ALPER. We would need a few minutes to set up also.

The CHAIRMAN. Well, the committee then can recess for 5 minutes while these companies make their setups and adjustments.

(Short recess taken.)

The CHAIRMAN. The committee will come back to order.

Now we have the presentation by Spacetronics; you are Mr. Bollum?

Mr. BOLLUM. Yes. C. W. Bollum, Sr.

The CHAIRMAN. What is your position with Spacetronics?

Mr. BOLLUM. I am chairman of the board, and president of the corporation.

The CHAIRMAN. Where are you located, Mr. Bollum?

Mr. BOLLUM. We are a District of Columbia corporation. We have our laboratories in Bethesda, Md.

The CHAIRMAN. Do you have a statement? We would be happy to have it at this point.

STATEMENT OF C. W. BOLLUM, SR., CHAIRMAN OF THE BOARD AND PRESIDENT OF SPACETRONICS, INC.

Mr. BOLLUM. Thank you.

I would like to introduce Spacetronics. Spacetronics was incorporated on October 8, 1958, in the District of Columbia. One of our first acts as a corporation was to purchase from Walter A. Crowley, the Hydro-Air Transportation Co. and all of Mr. Crowley's rights to, and interest in, patents, inventions, and other valuable information. Among these was the hydro-air vehicle.

We would like at this time to present a simplified version of the principle of the hydro-air vehicle. The underside of the vehicle is likened to a pie pan upside down. This is technically known as a plenum chamber. Into this chamber we pump air in large volumes at low pressure. Our average operating pressure is about two ounces per square inch. This pressure exerted upward lifts 18 pounds for each square foot of total horizontal area. Experimentally, we have lifted as much as 40 pounds per square foot.

As we pump air into the plenum chamber and the vehicle lifts above the surface of the earth, the air will leak out from around the bottom of the vehicle. The more air that we pump into the vehicle, the more air that will leak out and the higher we lift. We throttle our air pumping motors for the desired altitude. We have discovered that the hydro-air vehicle is stable in attitude at heights above the surface of the earth up to one-tenth of its equivalent diameter, and no controls are required other than steering and throttle controls for the thrust and the air pump motors. Further development and tests will be required before the upper limits of altitude without attitude controls can be determined.

Now that we are above the earth's surface with no friction between us and the earth, all that is necessary to move is to push ourself along.

This can be done in many ways. However, on our first models we will use propellers, which are completely enclosed with a shroud that protects the tips of the propellers. It will take very little power to move the vehicle at very high speeds. We estimate that our first models will travel at up to 100 miles per hour over the water.

For motors we plan to use automobile motors. In the much larger commercial vehicles we will probably use diesel engines. Preliminary data indicates that the hydro-air vehicles will be the most economical method available for the transportation of heavy loads over the water at great speeds.

At this time we would like to show you some motion pictures of demonstrations made by Spacetronics in November 1958. These demonstrations were made for the benefit of the military personnel connected with the Office of Naval Research. Among those who witnessed the various demonstrations were officers and civilians of the Army, Navy, Air Force, and Marine Corps.

This vehicle was first operated in the inventor's backyard and later was tested on one of the golf courses near his home. It was also demonstrated for the Army ordnance personnel at the Detroit Ordnance Depot.

This model was approximately 16 feet long and 10 feet wide. It was constructed of tubular steel covered with a fabric. It weighed approximately 550 pounds empty and used a four-cylinder McCulloch engine for an air pump and a two-cylinder Kiekhaefer engine for thrust and steering.

These engines were used drone aircraft engines which had been rebuilt by Mr. Crowley and in the manner used had an output of approximately 12 horsepower and 6 horsepower respectively. In spite of these handicaps, the vehicle, with the inventor aboard, floated about 4 to 6 inches off the ground and was stable in pitch and roll. It responded easily to the steering wheel which swiveled the thrust engine 360 degrees. It was possible to step out of the vehicle while the lift engine was running and leave the vehicle to float with no one at the controls.

During the demonstration shown in these movies, Mr. Crowley was having trouble with his air pump engine and as a result was only able to lift about 3 to 4 inches off the ground. In the film which shows the demonstration over the Anacostia River at Anacostia Naval Air Base, the first pictures over the water were taken while there were swells of approximately 1 foot height. As a result of only 3 to 4 inches of lift, it will be noticed that the bow of the vehicle caused a spray. On the second day when the water was very quiet and smooth, you will see that the vehicle left very little wake and only a slight ripple on the water. Unfortunately, during the naval air station tests, the motor failed on the second day and Mr. Crowley was able to make only one run over the water, barely reaching shore before his motor failed entirely. Since then all of our effort has been on research and development tests. At this time the film of the hydro-air vehicle will be shown.

I might say the reason we don't get any higher, is because we don't have any more horsepower. I hope it is dark enough for the film presentation.

(Film shown.)

The CHAIRMAN. What speed did you get out of it?

Mr. BOLLUM. Mr. Crowley operated this over a golf course in Detroit at close to 60 miles an hour, when his motors were operating properly.

The CHAIRMAN. What speed did he get on the water?

Mr. BOLLUM. On the water I would judge he was probably getting about 25, 25 to 30 miles per hour. His motor started acting up. The aircraft type motors used had not been waterproofed, and the water spray got on the spark plugs and for that reason, the motor failed very quickly. Fortunately it did, because we found afterwards a cracked hub; if he had continued to operate, one of the props might have come off and cut his head off. So we think the good Lord has been looking after us all along.

May I go on now?

The CHAIRMAN. Perhaps you had better proceed with your statement.

Mr. BOLLUM. Mr. Crowley's vehicle was capable of giving a reasonably good demonstration and very adequately demonstrated that a vehicle could be built which would make use of an air cushion for the purpose of destroying the friction that would exist between the vehicle and the earth's surface. However, it was apparent that there was a considerable amount of research and development required before Spacetronics would be in a position to offer to industry and the military, a vehicle which would be competitive.

As a result, the engineers of Spacetronics, Inc., made a detailed study of Mr. Crowley's invention and decided to investigate other methods of using an air cushion to lift the vehicle.

As a result a completely new principle for the development and utilization of the air cushion was conceived. This new principle, which was explained earlier, is considered by the engineers of Spacetronics to be far superior to the principle used by Mr. Crowley in his original vehicle.

As a result of the tests made, the corporation has decided to design and fabricate commercial vehicles and sport vehicles which we hope will be available for sale to the public within 18 months. We believe that we have discovered a principle which will enable us to produce a vehicle costing less per pound of payload than most other methods of transportation. It will also be able to transport that payload at a low cost per ton-mile.

Preliminary sketches have been made of the Hydro-Air Sport Vehicle and certain decisions have been made as to the method of construction and the motors to be used. This vehicle, when fully assembled and ready for operation, will be approximately 26 feet long and 20 feet wide. It will have a center section 8 feet wide which will carry all of the motorized equipment, air pumps, propulsion equipment, cabin, and baggage storage compartment. On each side of the center section there will be 6-foot-wide winglike sections.

Mr. Crowley, will you put the illustration on the easel?

These side panels or wings will be detachable and, if desired, can be placed on a rack above the vehicle so that the vehicle will meet the maximum width regulations of the highway departments.

We will also have wheels underneath so we can get very definite propulsion and brakeage which is also required by the highway departments.

It is estimated that this particular vehicle will have a maximum empty weight of approximately 4,250 pounds. It would have a payload capability of up to 9,250 pounds for a gross weight of approximately 13,500 pounds. Normal operating payloads would probably be on the order of 2,500 pounds which would represent the weight of approximately six passengers and 1,000 pounds or more of baggage. With this payload the vehicle would lift approximately two feet above the surface of the earth at full throttle. If we should increase the payload from 2,500 pounds to 9,250 pounds, the maximum operating height would then drop down to approximately 16½ inches. Thus, it can easily be seen that this vehicle can be heavily overloaded with only a small reduction in operating height. This vehicle will have a speed of up to 100 miles per hour over the water. The operator would have to throttle to a speed that would be consistent with the roughness of the surface to be traversed.

After studying the requirements for commercial vehicles, it was determined that the size of such vehicles would be so large that they could not be easily transported except over water. As a result, the engineering staff decided that a modular type of design should be considered and we are showing today our modular design for commercial vehicles.

The model that you see on the table has been built at a one-tenth scale. The black lines that you see on the vehicle represent the junction of the various modules. This is the same design as is covered in figure 1 of this document. You will notice when we demonstrate this model that it rises about 1 inch above the surface. This model has four used vacuum cleaner motors. They were rebuilt by us and installed in this vehicle. Each motor was recently checked and calculated to be one-fourth horsepower for a total of 1 horsepower for air pumping. The model weighs about 50 pounds which is approximately 3½ pounds per square foot. We had installed motors totaling 14 horsepower, representing the scaled down horsepower; this vehicle would rise off the surface of the table or floor a height of approximately 14 inches, because our height is in direct proportion to the horsepower or air-pumping capabilities.

It is linear, twice the horsepower, twice the air, twice the height.

However, if we should load the vehicle down to a total gross weight of approximately 250 pounds, which would represent approximately 18 pounds per square foot, then the vehicle would rise approximately 4 inches. This would be equivalent to one-tenth of the equivalent diameter of 40 inches.

Refer to figure No. 1. This vehicle would be 48 feet long, 32 feet wide, and would have a cargo area of 16 feet by 32 feet. It would have four air-pump units and one propulsion unit of two propellers both operated by the same motor. The empty weight of the vehicle is estimated to be 14,000 pounds and we estimate that the average fuel consumption would be 15 gallons of gasoline per hour.

With this vehicle we could carry a payload of 10,000 pounds up to a height of about 45 inches. We could increase the payload up to 40,000 pounds, and operate it at a height of about 30 inches.

You will notice that by increasing our payload by a factor of 4, we have only lowered our maximum height to 30 inches. We have discussed the construction of this vehicle with the Aluminum Co. of

America, and both of us estimate that this vehicle could be produced and sold for approximately $40,000, which would amount to $1 per pound of payload capability. If we assume a payload of 20,000 pounds or 10 tons at a speed of 50 miles per hour at a height of approximately 60 percent of our maximum, we would then be carrying 10 tons 50 miles and consuming 15 gallons of gasoline.

Thus, we would be carrying 33 tons 1 mile on 1 gallon of gasoline. At the present price of gasoline, this would represent roughly a cost of 1 cent per ton-mile. With the same payload and a speed of 100 miles an hour, we would burn 5 more gallons for propulsion, no more for lift. This would give us a total fuel consumption of 20 gallons per hour, or 50-ton miles per gallon of fuel.

We would like at this time to refer to figure No. 2. This represents another type of vehicle, using a different type of air pump module. In this vehicle the air pump module instead of being 8 feet by 16 feet in dimension and carrying one motor and one fan, now is 12 feet by 24 feet in dimension and will carry one motor of approximately 1,000 horsepower and two fans.

This vehicle would carry two propulsion modules. It would be 48 feet wide and 80 feet long and would have a cargo space of 32 feet by 48 feet. This vehicle would have an empty weight of approximately 32,000 pounds and would burn approximately 45 gallons of gasoline or other fuel per hour while operating at a speed of approximately 50 miles an hour, at an average operating height.

With a payload of 30,000 pounds, it could rise to a maximum altitude of 83 inches or approximately 7 feet. At 120,000 pounds, it would rise to 52 inches. The estimated price of this vehicle is $95,000 which is somewhat less than $1 per pound of payload. Although the operating efficiency of this model would be the same as the previous model, it would operate at a much higher altitude and if one desired to operate at the same altitude as the previous model, the ton-miles per gallon of fuel would be approximately double, or about 60 ton-miles per gallon.

We would at this time like to list very quickly some of the present uses for this vehicle. Among the military uses are vehicles ranging in size from a small, one-man vehicle which might be 10 feet long and 6 feet wide, up to a large transport vehicle which might be 100 feet long and 60 feet wide, on which a man could lay prone, perhaps steering with his feet, and could have a machinegun with him and scoot up rivers and bayous, near the ground with low silhouette.

These vehicles could be used in the polar regions over the snow, as rescue vehicles, as amphibious landing craft, as vehicles for the transportation of military equipment including tanks, for transportation over streams, flooded areas, mud, swamp, and so forth. Special adaptations to the vehicles could be made which would allow the vehicles to travel up and down hills as well as on the level ground. This vehicle could be used as a part of an antisubmarine weapon system.

Among the many potential civilian uses for such vehicles, perhaps the most readily apparent is its use as a sport vehicle which could be used by fishermen, hunters, or merely as a vehicle to replace the outboard motor or speedboat. Commercially, such vehicles could be used for transporting personnel and material to and from oil drilling rigs in the Gulf of Mexico, small islands off the coast, and the Texas Towers off Cape Cod. Vehicles could be built which would be able

to transport fish from the fishing fleets very rapidly to the market areas and transport men and supplies out to the fleet, enabling the fleet to stay in the fishing area for longer periods of time.

For future transportation, it is very possible that within a period of 5 or 6 years we may have ferry systems operating from Florida to South America via the islands, carrying automobiles, passengers, and cargo at speeds up to 100 miles an hour. It is also very possible that within the next 10 years a transoceanic vehicle will be built approximately 300 feet in diameter, operating up to 30 feet over the top of the water, at speeds of 200 miles an hour.

In closing I would like to make a few statements. The development of the hydro-air vehicle has been financed through private funds and no Government assistance, financially, or otherwise, has been offered or accepted by this corporation. The only assistance which has been received in the development of this vehicle was the furnishing of certain materials and information by the Aluminum Co. of America. Recent discussions with the Aluminum Co. of America have resulted in informal agreements to cooperate in the design and production of prototype models. In addition, they have indicated their desire to quote a cost price for the metal fabrication connected with the production models. As of to date, this corporation has spent approximately $10,000 in preparing and presenting proposals and preliminary drawings to the Government. As of the present time the only group of the Armed Forces who appeared to be interested in this vehicle is representative of the Marine Corps who have approached us in regard to the purchasing of a vehicle of the commercial variety, which they want to test in order to determine whether or not they are interested in further designs or purchases. We believe it would be a serious error in judgment if the Department of Defense decided that the principle of the hydro-air vehicle was inferior to the other principles being considered which have not as yet demonstrated a man-carrying vehicle over the ground or water.

In addition, after seeing the Ford presentation yesterday, we decided to bring our version of the airtrain, the air-bearing train in which we use a concrete rail which can be laid very quickly with a machine, designed for that purpose. It would be self-cleaning because of the slant; the snow, dirt, ice water and everything would run off. If it did not run off, it would not make much difference because we are still riding on 4 or 5 inches of air cushion. This type of train can be traveling at great speeds. It might be very economical to build. In fact, there is enough information available right now, we feel, for very serious design considerations.

The CHAIRMAN. Thank you, sir.

I commend you for proceeding without Government help of any sort, financially or otherwise. I think that is very fine, that private industry takes on and develops new phenomenon such as this on its own.

Are there any questions? Mr. Fulton has a question.

Mr. FULTON. As a matter of fact, you have proceeded without Government help, or it seems to me without Government encouragement.

The total cost of your research and development on this type of an operation, take your total overall, how much has that been?

Mr. BOLLUM. So far to date this corporation has spent approximately $50,000.

Mr. FULTON. Can you give us—not now but later—a statement showing a breakdown of research and development as to categories, where you spent it? Just the general categories.

Then, might I ask the staff if they will prepare and have for us the cost of the research under the Department of Defense in the various services on this particular subject as well as the results obtained by each and evaluate it for us, please?

(The research cost breakdown is as follows:)

PROGRAMS IN GROUND PROXIMITY RESEARCH

NAVY

1. ONR

a. Air Branch (Code 461)

(1) Contract Nonr 2398(00) with Aerophysics Company of Washington, D.C., for $30,000. Effective dates: October 1, 1958 to September 30, 1959. To investigate the theoretical aspects of the annular jet in and out of ground effect.

This contract was originally started on August 5, 1957 and the Summary Report AR 581-R "Aerodynamic Theory of the Annular Jet" was published in December 1958. It presents theories to describe the flow mechanics of air jets issuing from annular openings both in and out of ground effect.

(2) Air Branch efforts to survey the field and determine the extent of further research efforts. Dr. G. B. Matthews and Maj. J. L. Wosser will present a paper titled "Ground Proximity: A Critical Review," at the annual summer meeting of the Institute of Aeronautical Sciences in June of this year.

b. Mechanics Branch (Code 438)

(1) Contract Nonr 222(71) with the University of California (Berkeley) for $20,000. Effective dates: April 1, 1959 to March 31, 1960. To test small models over water at varying forward flight speeds and different wave conditions.

No results submitted to date.

(2) Contract Nonr 1509(03), NR 062-053 with Iowa State University for $30,000. Effective dates: September 1, 1958 to August 31, 1960. To test models over ground and water utilizing the large towing tank investigating various parameters.

No results to date.

(3) A contract under negotiation to purchase certain theoretical and experimental information from Mr. Carl Weiland of Zurich, Switzerland. (Approximately $2,300)

c. Bureau of Aeronautics

(1) Contract NOaS 59-6096C with Gyrodyne Co. of Long Island, N.Y., for $46,784. Effective dates: January 9, 1959 to August 1959.

To build and test a man-carrying ground proximity machine 6 inches in diameter capable of lifting a payload of 300 pounds.

No results to date.

(2) Contract NOaS 59-6167C with Convair for $49,622. Effective dates: May 1 to October 31, 1959.

To study the feasibility and practicality of very large vehicles as ocean-going transports.

No results to date.

(3) An experimental investigation with David Taylor Model Basin to build models and test is under consideration.

d. Bureau of Ships

(1) An experimental investigation with DTMB Hydro Group (Service Ship Allotment, R&D-NS 715-086 subtask 66) for $45,000. Effective dates: March 6, 1959 to June 30, 1959.

To build rectangular and circular models to correlate the work being done at University of California and Iowa State.

ARMY

1. Transportation Corps

a. Princeton Ground Effect Model Investigation

Contract DA 44-177-TC-517 was awarded in September 1958 to Princeton University for a theoretical and experimental program to provide additional information on lift, propulsion, stability, and control characteristics of annular

jet configurations in hovering and forward flight, both in and out of ground effect. This contract was terminated April 1959 and the program is continuing under contract DA 44-177-TC-524 (ALART).

Data has been obtained for a variety of two-dimensional and three-dimensional models differing in size, nozzle configuration, and flow conditions. This data is being utilized to develop empirical relationships and to provide a basis for correlation with theory.

Approximately $25,000 has been expended through March 31, 1959. The remaining funds ($110,000) are sufficient to complete present program.

b. Piasecki Aircraft Corp. Aerial Jeep

Contract DA 44-177-TC-449 awarded in July 1959 to Piasecki Aircraft Corp. for design construction and tests of a research vehicle to explore the aerial jeep concept.

The tandem-ducted-propeller research vehicle (employing tandem-helicopter-type controls) has been flown up to speeds of 20 miles per hour and to heights of approximately 20 feet. The research vehicle currently is being modified to install a 400 horsepower turbine powerplant as a replacement for the original reciprocating engines to reduce the vehicle weight and permit adequate exploration of the concept. Preliminary testing of the modified research vehicle has been initiated.

Approximately $1,310,000 of the authorized $1,383,000 has been expended to March 31, 1959. An additional $50,000 is estimated required to complete the research program.

c. Chrysler Aerial Jeep

Contract DA 44-177-TC-448 awarded in July 1957 to Chrysler Corp. for design, construction and tests of a research vehicle to explore the aerial jeep concept.

The tandem-ducted-propeller research vehicle (employing fixed pitch propellers and duct inlet and exit vanes) has been completed and preliminary testing is underway prior to initiation of flight testing.

Approximately $980,000 of the authorized $1,112,000 has been expended through March 31, 1959. Remaining funds are believed sufficient to complete the research program.

d. Curtiss-Wright Aerial Jeep

Contract DA 44-177-TC-397 awarded in July 1957 to Santa Barbara Division (formerly Aerophysics Development Corp.) of Curtiss-Wright for design, construction, and tests of a research vehicle to explore the aerial jeep concept.

The four-propeller research vehicle has been completed and preliminary testing is underway prior to initiation of flight testing.

Approximately $840,000 of authorized $897,000 has been expended through March 31, 1959. Remaining funds sufficient to complete research program inasmuch as contractor has agreed to participate in cost of program and will fund excess over that authorized.

e. Hiller Aircraft Corp. Downwash Impingement

Contract DA-44-177-TC-500 was awarded to Hiller Aircraft Corp. on June 30, 1958, to determine the characteristics of deflected slipstream and downwash and resultant effect of slipstream and downwash on movement of particles (sand and dust). Contract is currently suspended pending revisions to plan of test to more adequately obtain best data desired which was not foreseen at initiation of contract. Test rig has been constructed and limited calibration tests conducted. Initial funding was $83,000. Revised contract estimates now indicate that contract will cost approximately $119,030 with no increase in fixed fees. No additional funding has been authorized, however, $40,253 will be required to prosecute revised program.

2. Ordnance Corps

a. National Research Associates Contract

Scope: A study to determine the feasibility of obtaining a minimum ground pressure vehicle primarily operated in contact with the ground, but capable of being supported by a dynamically created cushion of air for operation over land or water.

Background: A feasibility study contract was executed with National Research Associates, Inc., College Park, Md., by the Army Ordnance Corps on April 30, 1959. The contract provided for construction and demonstration of miniaturized models and a scale model to prove the technical feasibility, and to furnish studies and reports of results.

Status: This contract will expire on April 30, 1959. However, in view of results demonstrated thus far, a supplement is being negotiated to continue this project and obtain specific test data for possible future application to a larger full-scale vehicle. An additional supplement is also being planned which would use fiscal year 1959 funds. These two supplements will extend the performance date of the contract well into late calendar year 1959.

Results to date: At this time the contractor has demonstrated the miniature models in air suspension over hard surfaces and water. A 5-foot by 10-foot model, powered by a four-horsepower motor and weighing approximately 100 pounds, has also been built and operated about 12 inches by 16 inches over rough terrain surfaces. Detailed data, based on studies and tests to date are being compiled.

Funding summary:

Fiscal Year 1958 $57, 700 Research and development
Fiscal Year 1959 $25, 000 Research and development (Firm)
Fiscal Year 1959 $29, 000 Research and development (Planned)

Contracts Nos.:

DA 36-034 ORD
2679 RD

Mr. FULTON. I do not believe the stenographer—the reporter—previously got the question I had asked.

How soon would you be able to put an operable model into production?

Mr. BOLLUM. Our present plans are to build the model that you see roughly sketched here. We are going into the design and production of this immediately for a prototype version which we expect to test late this summer.

Mr. FULTON. That is the modular model?

Mr. BOLLUM. That is the modular model just as it appears there. This is, of course, a rough drawing but illustrates its general configuration. This fall we hope to take this vehicle from the Chesapeake down to Miami, and stop at the various ports along the way. We hope to be able to deliver production vehicles by a year from this summer, probably later in the summer, of both the modular model and the sports vehicle which we have shown here, the purplish looking one. We do not have a big staff, so we do all of our own artist's work. Whether we are better artists or engineers, I do not know.

Mr. FULTON. How much would your sports model cost you? You may have a customer sitting right here.

Mr. BOLLUM. This has been estimated, and we have gone over these plans with other people. We feel we can sell this model for under $4,000, and make a very handsome profit.

Now, to show you why we can, we would like to have my assistants turn this model up so you can see the bottom of it, and you will see that there is really nothing intricate, and we do not have a lot of gadgets under there that make it very difficult to construct.

The CHAIRMAN. Turn around a little bit if you can so the other members of the committee can see it.

Mr. CROWLEY. This is aluminum, filled with Styro foam for flotation.

The CHAIRMAN. What do you have inside there?

Mr. BOLLUM. Foam plastic. We use that for stiffening. Would you like to turn it around so others can see it?

Mr. FULTON. What is the reason for your octagonal configuration?

Mr. BOLLUM. Simplicity of construction and cheapness. If you go into curved surfaces it costs you money, and we do not need the curved surfaces.

Commercially I do not think the average operator cares whether he has round corners or square corners. He is not looking for beauty; he is looking to be able to transport a heavy load.

Mr. FULTON. You amaze me; you are able to make this without a high tail fin, a high set of tail fins, whether they are necessary or not.

Mr. BOLLUM. Actually, we have two propellers there. By differentially controlling the two propellers, we will operate it as a boat.

Mr. FULTON. You do not need any high fins as on current models of automobiles.

The CHAIRMAN. You might need fins to sell them.

Mr. BOLLUM. We may put fins on our sports job, if it will help sell it.

Mr. FULTON. There is no particular necessity of revising our highway design, is there, for this type vehicle, for this type vehicle operating over the ordinary highway?

Maybe you are making all our highways obsolete all over this country, and our highway program will have to be revised before we go ahead and spend $75 billion on old-fashioned highways.

Mr. BOLLUM. Congressman, we think there is a lot of work to be done with the various highway departments in changing some of the rules and regulations; we feel that in the future you may have the grading to do that you have today, but instead of putting down ribbons of concrete, you may use some sod, and you will glide over the sod never touching it.

Mr. FULTON. There will be highways in the United States never used by any vehicle?

Mr. BOLLUM. That is right.

Mr. FULTON. Is there any reason why you had an elevated shape of the track in concrete, for the proposed railroad transportation—peak shape?

Mr. BOLLUM. Peak shape?

Mr. FULTON. Yes, sir.

Mr. BOLLUM. It is part of the design. It enables you to be stable in going around curves.

Mr. FULTON. Is the lower part of your vehicle shaped to take advantage of the V shape?

Mr. BOLLUM. It is shaped to take advantage of the V shape, yes, sir.

Mr. FULTON. But it is not necessary?

Mr. BOLLUM. We feel for proper utilization of that particular vehicle, and the proper utilization of the chamber design, different from Ford's, that the V shape would be necessary. We think it is good to have, because it is self-cleaning for one thing.

Mr. FULTON. A crown tip roadway, the ordinary type asphalt road, would not be suitable for this type vehicle, would it?

Mr. BOLLUM. No, it would not.

Mr. FULTON. And the vehicle, while it would be used in the frozen wastes of the north, I do not imagine it would be used in the Sahara Desert. Have you tried it over sand?

Mr. BOLLUM. We feel it would operate all right over sand, because actually, our exhaust velocity is in the order of a little higher than 60 miles an hour, 60 to 85 miles an hour, and even at these velocities some sand will blow, but the air column as it went out from under the ve-

hicle would die very soon. You would have perhaps, if it was fine sand, a sand cloud, but in heavier sand you might not have even that.

Mr. FULTON. Have you done any experiments, instead of having the exhaust move out of the sides equally, through putting it in a column of air either through a chimney or a labyrinth or something like that, up through the vehicle?

Mr. BOLLUM. No, we have tried to spend our money and time in order to get a vehicle on the market and have not had the time or money or personnel to look into other types of designs.

Mr. FULTON. The same with diesel fuel, I think you would have to get your exhaust above the height of the person on city streets. I wondered whether you had in any way tried to change your configuration to get advantage of the extra lift that you get and the friction of the air going up through some sort of——

Mr. BOLLUM. We think it will be a long time before you put it on the city streets. First the application is over water or snow or the plains. We are not yet ready for the highway.

Mr. FULTON. I would recommend that the services give you some attention first, and secondly, on the line of the pyramid approach to scientific development, they use many more small companies like you and encourage you especially when you are standing on your own feet.

The CHAIRMAN. Mr. Anfuso.

Before I recognize Mr. Anfuso, I want to say that we are very happy to welcome Mr. Hall back with us today. He has been absent because of illness. He is rugged again, he is back with us and we are happy to have him.

Mr. HALL. Thank you, Mr. Chairman. I am delighted to be back.

The CHAIRMAN. Would you like to ask any questions?

Mr. HALL. No, I believe not, thank you—at this time.

Mr. FULTON. May I ask Mr. Hall, can you use this on wheelchairs?

Mr. HALL. Yes, I was interested in that.

Mr. FULTON. We might try you out on it.

The CHAIRMAN. There are possibilities there.

Mr. Anfuso.

Mr. ANFUSO. Mr. Bollum, can you tell us a little bit about the background of your company? What were you doing before this?

Mr. BOLLUM. Well, I might tell you, it is a rather Alice-in-Wonderland type of thing.

I first heard about Mr. Crowley when I was Deputy Chief in the Washington office of the Army Ballistic Missiles Agency. As a matter of fact, the Army sent me to Detroit to see Mr. Crowley and see whether or not we would have any interest in his new idea, and upon reporting back to the Army they decided that, inasmuch as we were the Army Ballistic Missiles Agency, the only application would probably be a missile-launching rack. Inasmuch as they were not interested in missile-launching racks, they were not interested in the idea.

Consequently, after that I left ABMA and went with Fairchild Guided Missile Division as engineering assistant to the vice president and tried to sell it to Fairchild Corp. Fairchild Corp. looked at it but kept their tongue in their cheek and decided to turn it down.

After a year, I left Fairchild and went with another company and tried to sell several of their customers the idea. I finally resigned and

formed this company last October 1958, with one of the principal objectives being to take Mr. Crowley and his ideas and make something out of them.

This is what we are doing.

Mr. Crowley is a graduate engineer, who formerly worked with the Chrysler Corp. on the Jupiter and Redstone projects. Mr. Crowley is here.

Mr. CROWLEY. Yes.

Mr. BOLLUM. Mr. Crowley is the inventor of the idea presented in the movie. He is the man who built the vehicle you saw, in the pictures, in his garage and operated it around his yard to the astonishment of all his neighbors.

Mr. ANFUSO. Mr. Crowley, is this your first venture in business?

Mr. CROWLEY. Not entirely. I built a Benson Helicopter first, if you are familiar with that rotating-rotor type thing with no power. But I cracked it up twice. I decided to build something that would be safe. That is what we have now. You can shut it off; that is, all your motors can quit, and you will sit down nice and easy.

Mr. ANFUSO. When did you form Spacetronics?

Mr. CROWLEY. I formed a company in Michigan, and sold my assets to Spacetronics Inc.

Mr. BOLLUM. The incorporators were myself, my wife, and a man by the name of O. K. Bell, who is no longer a part of the corporation. I picked up his stock.

Mr. ANFUSO. When did you do that?

Mr. BOLLUM. We were incorporated on October 8, 1958, in the District of Columbia.

Mr. ANFUSO. I see. Mr. Crowley is now part of your company?

Mr. BOLLUM. Mr. Crowley came with us in November 1958, and is vice president and chief engineer.

Mr. ANFUSO. How many personnel do you employ?

Mr. BOLLUM. We are down to a bare minimum of Mr. Crowley and myself, and one technical assistant. At one time we had more, but we found the money was going out faster than it was coming in, so we pared it down to the very bare minimum. We all wear three or four hats.

Mr. ANFUSO. Do you sell any stock in your corporation?

Mr. BOLLUM. The Securities Exchange Commission will not let us sell stock until it is registered, which we are now in the process of doing.

The CHAIRMAN. I want to say this: Congress is in session. We have a bill coming up today. Unless there are some other questions, we had better adjourn.

Mr. DADDARIO. Is there any limitation to the use of this vehicle and its development in the efficiency of the air pumping system?

Mr. BOLLUM. In the efficiency?

Mr. DADDARIO. Yes.

Mr. BOLLUM. We have a very efficient air pumping system which we have designed and developed ourselves and on which we have applied for patents. As a matter of fact, we have found out we get better than 90 percent efficiency. We calculate the fuel being used and the work being done and we are getting 90 percent efficiency. This is rather phenomenal, but we have checked our figures many times with many models and it seems to work.

We actually pump approximately 3,000 cubic feet of air per minute per horsepower, and it seems to make very little difference what type of motor we are using, whether it is gas or electric.

Mr. DADDARIO. Then that is a different principle altogether than this model you have shown here?

Mr. BOLLUM. This model has our design of air pump, our duct and our fan combinations, which we have found to be very efficient.

We have made over 300 different experiments to arrive at this design.

Mr. DADDARIO. Thank you.

The CHAIRMAN. At this time I might say we will not be able to hear National Research Associates because we do have to adjourn. Our bill is up on the floor. It may come up in a few minutes; it may be a little longer, but we ought to be over on the floor.

I suggest to all the members that can, be present on the floor.

Mr. FULTON. Before you adjourn, may I say to you as a matter of encouragement, I will be your first commercial purchaser of one of your vehicles. You can take the order right now. I wish you every success. We want people like you—more people like you—in this economy. So, deliver it to me in Pittsburgh.

Mr. BOLLUM. Thank you.

The CHAIRMAN. If there is nothing further, we will adjourn until tomorrow morning at 10 o'clock.

(At 12:06 p.m. the committee recessed until 10 a.m., Wednesday, April 15, 1959.)

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
Washington, D.C., Wednesday, April 15, 1959.

The committee met at 10:08 a.m., Room B–214, New House Office Building, Hon. Overton Brooks (chairman) presiding.

The CHAIRMAN. The committee will please come to order.

This morning we will conclude the hearings that we have been carrying forward for the last few days.

We have this morning Mr. William H. Alper, president of the National Research Associates, Inc., and he will be backed up by Mr. Melville W. Beardsley, vice president, National Research Associates, and Mr. Paul Denn, Ordnance Tank Automotive Command.

Mr. Alper, would you have a seat there, sir? Would you want Mr. Beardsley to be with you?

Mr. ALPER. Yes, please; Mr. Denn.

The CHAIRMAN. The committee attendance may be a little off this morning, I might say for the record, because some of the members had agreed to go to Las Vegas. As a matter of fact, the chairman intended to go, but due to legislative schedule on the floor I canceled my plans at the last minute. Some of the members are attending. However, we will have a pretty good attendance this morning in spite of that.

Mr. Alper, you have a prepared statement, haven't you?

Mr. ALPER. Yes, sir.

The CHAIRMAN. Will you proceed with that, sir.

Mr. ALPER. Yes, sir.

STATEMENT OF WILLIAM H. ALPER, PRESIDENT, NATIONAL RESEARCH ASSOCIATES, INC.; ACCOMPANIED BY MELVILLE W. BEARDSLEY, VICE PRESIDENT, NATIONAL RESEARCH ASSOCIATES, INC., AND PAUL DENN, ORDNANCE TANK AUTOMOTIVE COMMAND

Mr. ALPER. Mr. Chairman, members of the committee, I am pleased to have this opportunity to appear before this committee today particularly in view of the fact that the subject which I will present is one on which we have been doing missionary work for 4 years.

To begin with, I would like to clearly define the type of vehicle and its operating principles about which we are talking. The vehicle under development by National Research Associates, Inc., incorporates the free air suspension system. Other titles which have been used for vehicles of this type are minimum ground-pressure vehicles and the airborne surface vehicle. This type of vehicle employs a peripheral jet which generates and contains pressure underneath the vehicle to provide it with support. In other words, this vehicle rides on a cushion of air which is contained by an air wall.

In order to prevent any confusion concerning the peripheral-jet vehicle as compared with other vehicles which, at first glance appear similar, I would like to point out the basic differences between vehicles of our type and such others as ducted-fan vehicles and air-bearing vehicles. In order to highlight some of the significant differences I would like to refer to the three charts which point up the basic characteristics and allow comparison to be made.

You will note from a comparison of the charts that the peripheral-jet vehicle of the type we have pioneered develops its lift by a combination of pressure lift and jet thrust, whereas ducted fan vehicles rely completely on air thrust and the air-bearing vehicles depend completely on pressure lift. Hence, the lift effectiveness of our peripheral-jet vehicle is greater than either of the other two types. This lift effectiveness is indicated, for example, by the greater lift per horsepower obtainable with vehicles of our type.

In regard to mobility, a most important operating characteristic for military vehicles, our peripheral-jet vehicle can traverse any type of terrain surface with a ground clearance which is determined by the power and load characteristics. The ground clearance would normally be several feet. The air-bearing type vehicles have restricted mobility capability because of the fact the ground clearance is limited. For instance, it has been stated that the Ford "Levapad" is intended to operate with a clearance of only a few thousandths of an inch and thus requires a smooth track upon which to operate. The ducted-fan vehicles, being in reality a type of aircraft, operate independently of ground conditions but have the various limitations regarding operation on the ground that are inherent in aircraft. In addition, the operator must be a trained pilot. As previously stated, since the peripheral-jet vehicle at all times operates in close proximity to the ground it inherently needs lower horsepower for a given weight vehicle.

The basic functional characteristics of our peripheral-jet vehicle make possible its operation by personnel who have had no more training than that required to drive an automobile. By contrast, ducted-

fan-type vehicles have some inherently unstable characteristics and pilots for these vehicles will require training comparable to that given pilots of other aircraft or helicopters.

Having discussed some salient operating characteristics I would like to refer you to these simple charts, exhibits I, ducted-fan, II, air-bearing, and III, peripheral-jet, which illustrate the basic operating principles of these three type vehicles. You will note that ducted-fan vehicles are supported by the brute force of downward blowing of air. The air-bearing vehicles are supported by pressure under their bottom surfaces, the amount of pressure developed being determined by the rate of flow leakage allowed by the height of the edge of the vehicle above the ground. You will note that the air flow leaving the air-bearing vehicle is horizontal so that no vertical thrust is secured from it. Referring to the chart for our peripheral-jet vehicle you will observe that the peripheral-jet sheet is ejected downward from the vehicle so that a thrust lift is secured; and in addition, through its reaction with the ground, the peripheral jet generates and maintains a lifting pressure acting upward on the vehicle's bottom surrounded by the peripheral jet. You will also note that we have included some typical figures to give a comparison of lifting efficiency. For instance, a ducted-fan vehicle will require in the order of 350 hoursepower to lift a gross weight of 1 ton; whereas a vehicle of our peripheral-jet type would require in the order of only 50 horsepower, this difference in horsepower being largely due to the fact that the peripheral-jet vehicle operates in close proximity to the ground.

By comparison we have pointed out that our peripheral-jet vehicle, or free air suspension system, is distinctly unique as compared with vehicles of the ducted-fan or air-bearing type.

BRIEF HISTORY

Since 1954 the founders of National Research Associates, Inc., have been attempting to arouse sufficient interest in, and obtain support for, research and development in this type of vehicle. Our experience was typical of the history of most new ideas. Our records show that we contacted 53 industrial companies or Government agencies in the process of looking for support. Our list of companies reads like a "who's who" of industry. We found that most people would listen to our presentation and agree that the concept was interesting and that if it worked it would provide vehicles with high mobility characteristics. However, due to lack of foresight, courage, or funds, no support was obtained until our contact was made with Ordnance Tank-Automotive Command at Detroit.

As an example of our efforts in trying to interest the various branches of the Armed Forces in this new concept for high mobility vehicles, we retained the services of Dr. Gabriel Boehler to perform an independent analysis of our concept and to assist us in preparing our proposal which was titled "The Airborne Ground Vehicle—A New Device For Improving Tactical Mobility of Ground-Based Military Units." This was submitted to the U.S. Army on January 8, 1957. This effort met with little success. It did, however, act as a catalyst in stimulating interest in high mobility vehicles. BUAER of the U.S. Navy and other service groups were contacted by us in the hope that one of the services would undertake to support research

on this vehicle. During all this time we continued our own research and development program with our own very limited funds and it wasn't until a representative of Ordnance Tank-Automotive Command, Detroit, Mich., heard about our concept and contacted us for a demonstration that we were finally able to obtain a sponsor. I would like to add parenthetically that it is largely because of this support by Ordnance Tank-Automotive Command that there is so much interest in this type vehicle today.

Shortly after demonstrating our concept to Ordnance Tank-Automotive Command at Detroit Arsenal, we received our first contract to build a feasibility model. This contract was for a very modest amount—$50,000. By utilizing off-the-shelf equipment and modifying standard hardware, and by designing for low cost instead of high performance, we were able to design and build a 5- by 10-foot operating vehicle which proved the technical feasibility of this concept.

We have in addition developed a design which achieves complete inherent stability. A basic annular-jet vehicle is not inherently stable, but through incorporation of a proprietary design which we had conceived and developed prior to our Government contract, we have achieved complete inherent stability which makes these models capable of operating over irregular terrain with inexperienced operators.

Our Government program is currently devoted to development of controls and testing to secure engineering data which can be used for the design of full-scale vehicles. The program contemplates the construction of a full-scale test rig.

FUTURE POTENTIALITIES

Forecasting the potentialities of free air suspension system, or peripheral-jet vehicles, depends on a full understanding of the concept and an unimhibited view of the operating functions which it can perform. For combat vehicles it will provide extremely high mobility since it can operate over a wide variety of terrain and surface conditions. Using its wheels, it can be driven in and out of buildings and along city streets and highways but, in addition, when there are no paved surfaces it can lift itself off the ground and traverse terrain surfaces such as water, ice, snow, mud, desert sands, and arctic tundra. Here we wish to reemphasize that this is a surface vehicle—a high mobility vehicle capable of traveling in close promixity to the ground and capable of clearing most obstructions found on the earth's surface.

Combat vehicles whose mobility characteristics would be greatly enhanced by the employment of the free air suspension system are considered to include combat reconnaissance and tactical vehicles such as light tanks.

Considering the high mobility capability of this type vehicle other applications to such uses as missile carriers, logistic carriers, assault craft, and others come to mind.

As pointed out earlier, the complete inherent stability of free air suspension system vehicles permits their operation by personnel requiring no special training. This feature is of the greatest importance considering the possibility of rapid mobilization and utilization of untrained personnel and minimization of training costs and time.

An interesting technical feature of this type vehicle is that in its normal operating regime a 100 percent increase of the gross weight decreases the operating height by about 50 percent. This feature allows great increases in useful combat load conditions where the terrain features are comparatively even. It should be noted that an increase of useful load equal to 100 percent gross weight at least triples the payload. This characteristic allows great flexibility of operation.

Another interesting feature of our free air suspension system vehicle is that the lifting efficiency with which it operates with a given ground clearance increases directly with size. In other words, the larger the vehicle the greater the payload lifted per horsepower. Consideration of this feature leads to a visualization of some extremely interesting possibilities.

The future potentiality of the free air suspension system vehicle will become more clearly defined as the program develops. However, even at this time some sophisticated analysts have predicted that within 10 years the majority of combat vehicles produced will operate utilizing the free air suspension system.

RATE OF FUTURE PROGRESS

The free air suspension system vehicle is basically simple. For instance, it is lifted by pressure over its entire bottom surface so that it is simply sitting on a cushion of air. It is stable in height and attitude. It is easily controllable and there are no potentially hazardous or catastrophic conditions which will be encountered to retard progress. As in any new type of machine, refinements will be made; but even today we have sufficient knowledge and experience to immediately build preliminary high mobility test vehicles.

Because of our faith in the great future for this type vehicle and in anticipation of an accelerated program, National Research Associates, Inc., has assembled a capable management team and arranged for facilities and financing which would be required to rapidly accelerate the rate of development of these vehicles. Our associate, Turbo Dynamics Corp., has made available over 500 acres in its industrial park in Minden, Nev., for facilities to manufacture these vehicles and test them over representative terrain. It has also provided financial and management assistance.

In conclusion, therefore, the rate of progress which can be made in developing and introducing free air suspension system vehicles into the operational inventory depends directly upon the rate at which development is funded in the near future. It is considered that an optimum rate to expeditiously expand the state of the art with efficient expenditures employing the management team and facilities available would be $1 million for fiscal year 1960 growing to $5 to $10 million for fiscal year 1961. Our recommended program to be supported by this expenditure includes the construction and testing of a full-scale test rig in fiscal year 1960 to confirm existing theory and small scale test data which we have developed to date, and to secure additional reliable data for the design and performance estimation of full-scale operational vehicles. In the latter half of fiscal year 1960 it is recommended that the preliminary design of prototype combat vehicles be initiated and that three such prototypes be constructed in fiscal year 1961 for service testing.

Funding after fiscal year 1961 will be determined by the military requirements resulting from the impact of this new concept on military thinking.

At this point we had planned to include a demonstration but we had it yesterday afternoon after the hearings.

In conclusion, the free air suspension system, like the tank of World War I and like the atom bomb of World War II, will give the United States an advantage not now enjoyed by any potential enemy. That is, a high mobility capability over all types of terrain. This means that we will be able to rapidly transport troops and equipment into trouble areas of the world during the limited wars without stripping ourselves of our air transport capabilities.

National Research Associates, Inc., is a new and small company but we are uninhibited by restrictions of size and the demands of current production as we have shown in our early work on the free air suspension system vehicles. We are capable of moving fast into a new era and exploiting to its utmost the new type of technology which we have pioneered with the Army Ordnance Tank-Automotive Command.

I thank you, gentlemen.

The CHAIRMAN. Thank you very much.

I would like to ask you, Mr. Alper, something about the National Research Associates, Inc.

You are located at College Park, Md.

Mr. ALPER. That is right, sir.

The CHAIRMAN. How large a company do you have, and what is the history of your company?

Mr. ALPER. Well, sir, we originally were formed about a year and a half ago, and we were incorporated in the State of Maryland. We currently have 15 full-time employees, of which 8 are engineers. We occupy some 4,000 square feet of space. Our plans are to rapidly double this space for this coming year.

The CHAIRMAN. You have this one Government contract. Do you have any other Government contracts?

Mr. ALPER. No, sir; we do not have any other Government contracts at this time.

The CHAIRMAN. This one contract is with the Ordnance Command?

Mr. ALPER. That is right; U.S. Army Ordnance Command.

The CHAIRMAN. It is in Michigan?

Mr. ALPER. Detroit; yes, sir.

The CHAIRMAN. Detroit.

Is it your thought that your type of vehicle would be fitted perhaps—or rather your type of mechanism would be fitted perhaps to the use of tanks?

Mr. ALPER. Yes, sir.

The CHAIRMAN. That is the reason the Ordnance Command is interested in furtherance of the development of it?

Mr. ALPER. That is our understanding of it, sir. Tanks, or reconnaissance type vehicles, and tactical vehicles.

The CHAIRMAN. You have with you this morning Mr. Denn. Is Mr. Denn with the Ordnance Tank Command at Detroit?

Mr. DENN. Yes, sir.

The CHAIRMAN. So you are with the Government, rather than with the National Research Associates?

Mr. DENN. That is right, sir.

The CHAIRMAN. What is your position with the Government?

Mr. DENN. At the present time I am Chief of the Preliminary Concept and Evaluation Section in the Advanced Vehicle Design Branch of the Research Division.

The CHAIRMAN. You are out of Detroit?

Mr. DENN. That is right, sir.

The CHAIRMAN. Without giving any military secrets away here, and if you have anything of that sort we can go into executive session, what is now the attitude of the Ordnance Command toward this type of vehicle?

Mr. DENN. The Ordnance Tank Automotive Command believes that this is an extremely promising device to be utilized on the lighter weight combat and tactical vehicles. We intend to employ this device as stated by Mr. Alper previously as an adjunct to wheels which would also be employed on the vehicle. We believe that wheels would be necessary for some sort of ground maneuvering, on roads, and that sort of thing, and also that in the event of engine failure it would be very nice to be able to tow the vehicle without having to skid it over the ground. We feel that with a combination of a little wheel system that is not the complete suspension heavy spring type thing we have been used to in the past, that we can come up with a significantly lighter vehicle and a much more mobile vehicle than we have presently been capable of producing.

The CHAIRMAN. Now, you have in mind that this would give you a tank with three methods of transportation: One, by land; two, by air; and three, by water?

Mr. DENN. This is essentially correct. However, we don't consider this to be a flying device inasmuch as we don't consider that this vehicle will go anyplace that some of our lighter weight combat vehicles will go today. We do have the amphibious capability today in some vehicles.

The CHAIRMAN. This gives you a little more than amphibious capabilities.

Mr. DENN. Yes, sir.

The CHAIRMAN. It gives you the three types of transportation there, although you would not conceive of this as being a flying machine in any sense of the word.

Mr. DENN. That is right, sir. We don't visualize going higher than in the neighborhood of 5 feet off the ground. The reason for the selection of this figure is, a good many natural obstacles, hedges, and that sort of thing, and also fencing that is normally in use is approximately that height.

The CHAIRMAN. Would you envision a tank flying along at a height of 5 feet over these hedges—Army tanks?

Mr. DENN. A light tank.

The CHAIRMAN. What do you mean by light? Forty tons?

Mr. DENN. No, sir. Something in the order of the personnel carrier devices that are currently employed by the Army as personnel carriers. I'm hesitating here, because I don't want to get into classified areas. I think there are a great many vehicles that are known to members of the committee and to the public in general, such as the T–113 and others that this system could be employed on very effectively.

The CHAIRMAN. This system would really substitute for the air-filled tires of an automobile.

Mr. DENN. Yes.

The CHAIRMAN. In other words, you now cushion yourself with automobile tires. If it were applied to automobiles, it would cushion the automobile with air rather than tires.

Mr. DENN. That is right. Of course, the most significant capability is the ability to have a vehicle that normally does not have the ability to traverse cross-country terrain, because it only has wheels on it, and with this device it does have that capability. I might add we feel that it has the capability of going at much higher speeds than our present cross-country track vehicles are capable of going.

The CHAIRMAN. And with less vibration?

Mr. DENN. Yes, sir.

The CHAIRMAN. That is correct; isn't it?

Mr. DENN. Yes, sir.

The CHAIRMAN. A good deal less vibration.

I am from the State of Louisiana. They are doing a lot of drilling there out in the marshlands and in the gulf.

I'm wondering if this sort of vehicle would not be adaptable to use by the oil companies in that sort of operation. For instance, now they use amphibious airplanes down there that land on the water or on land, but it would seem to me that in those canals down there, you might use this type of vehicle and also for going out in the gulf 15 or 20 miles. This vehicle might be usable in drilling operations, and when you come back on land it would still be acceptable. Is that correct?

Mr. DENN. That is correct, sir.

Mr. ALPER. We have given a license on the commercial rights to these vehicles to a company called Pegasus Industries. This is a comparatively new group to exploit some of these civilian applications that you mentioned. It is our understanding a vehicle prototype for commercial use will be in operation sometime this summer.

The CHAIRMAN. Also, it would seem to me you establish the principle in size which permits greater capacity lifting.

Mr. ALPER. Yes.

The CHAIRMAN. Per horsepower. That is correct, isn't it?

Mr. ALPER. That is correct, sir.

The CHAIRMAN. The larger the spread, the greater is going to be the efficiency of the operation.

Mr. ALPER. That is right, sir.

Mr. ANFUSO. Mr. Alper, some of these questions which our chairman has been asking you I am sure have been prompted by the fact he was a tank officer and also spent 23 years on the Armed Services Committee.

Obviously, you present vehicles which certainly can be used in time of warfare as a tank, for example.

Have you thought about the subject of the peaceful uses of such a vehicle?

Mr. ALPER. Yes, sir; this Pegasus Industries is actually an affiliate corporation, and is a small group engaged in determining useful commercial applications, or civilian applications.

Mr. ANFUSO. Can you tell us some of the commercial uses of this vehicle?

Mr. ALPER. Yes. Would you like to interject anything?

Mr. BEARDSLEY. You go ahead.

Mr. ALPER. Well, as the chairman indicated, uses of it in the marshlands and offshore drilling.

Mr. ANFUSO. Yes, I heard that.

Mr. ALPER. Other applications would be: We understand there is a problem on fishing vehicles, shrimp boats, out off the coast, where fishermen have to wait quite a while to bring their catch in to market. Sometimes, because the tides aren't right, they have to stand offshore quite a while. This presents quite a problem, because fish spoil rather rapidly.

This would be a way of having a type of vehicle that could go out to unload the vessels of their catch, and bring the shrimp catch, or fish, in to market lots faster, and the fleet could stay out much longer. We can see this in the areas of high-speed ferry operations, such as you find down in the Keys, or down in Puerto Rico. Also, the use by people who live on some of these little islands off the Florida coast.

Mr. ANFUSO. Could it be used, for example, to open up new highways?

Mr. ALPER. That is one of our thoughts on this thing; it would have a tremendous impact, economically, on those backwood areas where the major problem is to develop a highway system, but if there was a river or some fairly level terrain, there would be no need for going in and putting in a hard surface road. You could use this type of vehicle to open that up.

Mr. ANFUSO. It would be a lot more practical.

Mr. ALPER. Yes, sir.

Mr. ANFUSO. Let's get down to the cost, supposing that were the case. What do you estimate the cost of such a vehicle would be? Give us costs of different sizes. Have you thought about that?

Mr. ALPER. We have given that a good deal of thought. Mr. Beardsley has been doing some work on it.

Mr. BEARDSLEY. At this time, since we would like to have some way of giving our estimates, we are not really prepared to give any specific cost figures.

However, I think you have to examine something like this on a capital-required point of view, and when you consider that no roadways are required, or even if you have a forest area, you bulldoze out a pathway that by minimizing the capital investment in roadways you can afford to put more into your equipment. But even at that, our present views of the equipment, by maintaining high-speed, minimum-maintenance requirements for the roadways, will give very low cost per ton-mile of freight carried. And the sizes we feel, can be quite large, particularly in view of the increase in efficiency with size.

Mr. ANFUSO. I can see a lot of Government uses for peaceful purposes, such as we are talking about now—highways.

How about the mail? Could they use this type of vehicle to carry the mail in rural areas, for example, much faster, instead of by the ordinary truck vehicle?

Mr. BEARDSLEY. I would say particularly our studies show whereever you have a change of loading operation, changing from one type of transportation to another, a vehicle of this type shows up to its best advantage.

In other words, it goes, say, from the center of a town, to the edge of town, across some water to another whole land area with no change of loading and in one operation. So for special conditions, it appears that this would be an efficient means of transportation. However, our present feeling is that for highway use this vehicle really isn't practicable. If you have wheels, you are going to be more efficient to use the paved surfaces that you have.

The CHAIRMAN. Crossing at New York, from Manhattan to Hoboken, it could be used.

Mr. FULTON. It would be a lot faster than a change to a ferry.

Mr. BEARDSLEY. If you let your imagination go, you can imagine some very interesting situations just like that.

Mr. ANFUSO. The Army, the Navy; I suppose your principle dealings have been with the Army?

Mr. BEARDSLEY. Our results have been with the Army.

Mr. ALPER. Ordnance, yes.

Mr. ANFUSO. Are you getting pretty good results?

Mr. DENN. Yes, sir.

Mr. BEARDSLEY. I might say we are very heartened by the Ordnance Tank Automotive Command's attitude on this. They took it at an early stage and pushed it rather rapidly.

The CHAIRMAN. Mr. Osmers?

Mr. OSMERS. There were just one or two questions, Mr. Chairman.

What about fuel consumption in these various types of possible vehicles? Would that be very heavy?

Mr. ALPER. Are you speaking of various types, the ducted fan, or just our own?

Mr. OSMERS. The three types.

Mr. BEARDSLEY. In general, these types require power to sustain themselves off the ground. The use of power requires fuel flow. Now, when you consider a transportation application you are concerned with how far you go and how much you carry for a given amount of fuel. So that even though you are standing still, you require a considerable amount of fuel, depending on the horsepower, but if you go at a high enough speed your fuel consumption may be on the order of some conventional means of transportation in use today.

Mr. OSMERS. Well, Mr. Chairman, my thought there was in applying it to a military use where your fuel consumption which provides both the cross-country and the lift might be so high as to make it an impractical proposition from the standpoint of the weight of fuel that would have to be carried.

Mr. DENN. Sir, if I might answer that question.

We have made some calculations to determine just what order of magnitude we were in on this fuel consumption, and I think based on the fuel consumption of our present cross-country vehicles, and injecting the fact that we expect an increase of mobility over the same cross-country terrain on the order of 100 percent, we believe this system will be every bit as efficient as our present track vehicle.

Mr. OSMERS. Are you taking that on a ton-mile basis, roughly, or do you have to use a new equation in order to get the lift and the movement?

Mr. DENN. There are some new equations involved in it.

As an example, if we took a present conventional track vehicle that was designed for cross-country operations, and we employed the same box, but utilizing this sort of system in place of the tract suspension system, we would have a decrease in the weight of the vehicle on the order of 20 percent. This certainly would influence the problem. As an example, if we had the job of carrying 10 people in a personnel carrier 100 miles cross country, we believe we could build a vehicle utilizing this suspension system, and also auxiliary wheels, and get the people over this 100 miles for less fuel and in approximately half the time.

Mr. OSMERS. What would your optimum height above the ground be with these things, within some rough average?

Mr. DENN. From the fuel economy point of view, of course, is to get it as low as you can.

Mr. OSMERS. Obviously.

Mr. DENN. We feel the maximum height it would be operated at would be in the neighborhood of 5 feet.

I think the particular ground conditions that you were traversing would determine to a very great extent the height to which you would go.

In this system we have the latitude of selecting the height you wish to go, depending on the type of terrain you are traversing.

Mr. OSMERS. Mr. Chairman, would not the unevenness of the ground over which you were traveling reflect in the stability of the vehicle?

Mr. DENN. We have not witnessed this so far.

Mr. OSMERS. You haven't so far. Our chairman mentioned the possibility of using a free air suspension system of this kind over water.

Would high waves have any particular effect upon the operation of the free air suspension system?

Mr. ALPER. To answer this question—it would depend greatly on the size of the vehicle. The vehicle in the smaller sizes would, of course, operate only about 5 feet off the surface, of any surface, so if you had a high wave of 6 or 7 feet in a small vehicle, it probably would create a few problems. But if you had a much larger vehicle, this would be no problem. In other words, the height above the surface is a function of the size of the vehicle.

Mr. OSMERS. In other words, your problems in that particular regard would run fairly close to the problems you would have in boat operations. That is, if you had a 25-foot boat your wave effect would be, of course, a great deal more than it would be for a superliner of 1,000 feet. I understand that.

Mr. ALPER. Yes, sir.

Mr. OSMERS. There was one other question prompted by something which our chairman said in an off-hand way, about crossing the Hudson River from New York to Hoboken. I represent some of that territory that is across the river from New York, and we have great problems in moving large numbers of commuters across that river. It seems a little apart from our work here, but the cost of digging tunnels around that river run around $250 million, and the cost of operating ferryboats seems to be more than the railroads can bear.

I wonder if platforms, personnel-carrying platforms, might be feasible for carrying a large number of people short distances as across a river of a mile or a mile and a half?

Mr. ALPER. One of the thoughts we meant to mention when Mr. McCormack had asked——

Mr. ANFUSO. Thank you, sir.

Mr. ALPER. Mr. Anfuso, I'm sorry, sir.

Mr. FULTON. You should thank the gentleman.

Mr. ANFUSO. I did thank the gentleman. Majority leader and most distinguished Member of the House. I do thank you.

Mr. ALPER. Our thought was to have it for interurban and interstate transport, high-speed, rapid-transit systems, and our thought was on one of the studies we had made earlier in the game. It wasn't a very complete study; it was an application for a high-speed transit system, say from Washington, D.C., to New York City, making use of a right-of-way. This would go along pretty near what you are suggesting on a platform capable of carrying a number of people at a high speed fairly close to the surface.

Mr. OSMERS. Mr. Chairman, that brings forth another question.

If you operated such a system between here and New York, you would, of course, at the end of the run go through the Pennsylvania Railroad tunnel under the Hudson River. I think there are several other tunnels; for example, at Baltimore and Philadelphia.

Would the operation or the effect a vehicle of this kind would have upon the air, make tunnel operation impractical or difficult?

Mr. BEARDSLEY. It would not have any basic effect, as we see it, because you are supported by a surface. What is above, in effect, is immaterial.

Mr. OSMERS. The height or the character or quality of the airspace above the vehicle would not have any effect upon its capability?

Mr. BEARDSLEY. No, sir.

Mr. OSMERS. You feel it would be possible to control the height and keep it constant, that it would be practical for a tunnel operation or a subway operation where you would have to stay probably within a range of a couple of feet in some places?

Mr. ALPER. We envision a much closer operation to the ground than a couple of feet where you have a right-of-way, which is fairly level and the grading is fairly controlled on, we could operate very, very close to the surface.

Mr. OSMERS. Say an inch or something of that kind?

Mr. ALPER. That is right. And you could have a very high speed. On the order of 200 knots.

Mr. OSMERS. The point I apparently didn't make was you would have a stability of height?

Mr. ALPER. Oh, yes.

Mr. OSMERS. That I think would be the most important factor in operating through a tunnel.

Mr. ALPER. Right.

Mr. OSMERS. Now, would your vehicles in that particular regard have to have any different vertical height than a railroad car, for example?

Mr. ALPER. I believe they can be designed pretty near the same configuration as a railroad car. They would be slightly different shapes, but they would be able to operate within the same limits of the current railroad train's operation.

Mr. OSMERS. That is very interesting testimony. That is all I have, Mr. Chairman.

The CHAIRMAN. Mr. Mitchell?

Mr. MITCHELL. No questions.

The CHAIRMAN. Mr. Wolf?

Mr. WOLF. I don't have any questions. I don't think my imagination is adequate to keep up with the questioning going on here today. But good luck with your work. I'm behind you.

The CHAIRMAN. Mr. Moeller?

Mr. MOELLER. No questions.

The CHAIRMAN. Mr. Bass?

Mr. BASS. No questions.

The CHAIRMAN. There is one more thing I would like to ask since my mind goes back to the military features of the vehicle and since the military has indicated an interest in it.

I notice in your brochure here you say this sort of vehicle could traverse a mine field safely. In other words, the mine fields that we know about at the present time are operated mostly on contact, aren't they?

Mr. ALPER. Yes.

The CHAIRMAN. Rather than on magnetic initiation.

Mr. ALPER. Sir, there is one feature of this vehicle which I don't think we brought into the picture except rather briefly when we speak of minimum ground pressure vehicle. The pressures contained under the vehicle are very low. They are on the order of 20 pounds per square foot. Most people speak of pounds per square inch, rather than square foot, but we are speaking of such low pressures, almost like a gust of wind.

The CHAIRMAN. That would be about a pound and three-quarters per square inch.

Mr. BEARDSLEY. No, sir.

Mr. ALPER. It is less than that.

Mr. BEARDSLEY. It is about 5 percent of the pressure you would exert if you stood on one foot, and your weight was uniformly divided over your foot—a lot less than the pressure of a man walking on it. It is about one-seventh of a pound per square inch.

The CHAIRMAN. In effect, then, it would mean your vehicle would weigh less in the air than it does on the ground.

Mr. DENN. There are a lot of square inches there.

Mr. ALPER. I would think the weight of the vehicle would be supported over the entire base, rather than at one, two, or three points, as a car is supported. The same weight would be there, but it would be over a larger area.

The CHAIRMAN. I think that covers it pretty well.

Mr. MOELLER. May I ask one brief question, Mr. Chairman?

The CHAIRMAN. Yes.

Mr. MOELLER. On the basis of your research now, did you give credence to the possibility of such a thing as a flying saucer?

Mr. ALPER. Sir, I really don't know.

Mr. MOELLER. There is certainly a definite relationship between this and what we think is a flying saucer, is there not?

Mr. ALPER. Sir, this type of vehicle doesn't fly. I might draw an analogy.

The air that we have flowing under the vehicle supporting it is in essence the rubber tire, except instead of a rubber tire we have

faster moving air which contains the air pressure that your car currently sits on. So we are actually a surface vehicle.

Mr. MOELLER. There could be no relationship between this and the possibility of a flying saucer?

Mr. ALPER. As far as I can see; no, sir.

The CHAIRMAN. You are a surface vehicle, but when you get 5 feet above the ground——

Mr. ALPER. Sir, it is like a vehicle with a larger tire, that is all. It still has to have the ground for support. If you take the ground away, it can't stay.

Mr. FULTON. If you are a surface vehicle, don't you have to have the high rear fins?

[Laughter.]

The CHAIRMAN. Any further questions?

If not, I want to thank you very much, sir, for a very lucid explanation of this phenomenon. We appreciate it very much.

Now, we at this time will go into executive session to hear the military witnesses. We will excuse the other witnesses.

(Whereupon, at 10:55 o'clock a.m., the committee proceeded in executive session.)

HOUSE OF REPRESENTATIVES.
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
Washington, D.C., Wednesday, April 15, 1959.

The committee met at 10:58 a.m., Room B–214, New House Office Building, Hon. Overton Brooks, chairman, presiding.

The CHAIRMAN. Are we all cleared now?

Close the door, and we will go into executive session.

Let us hear from Brig. Gen. Frank H. Britton, Director of Developments, Office, Chief of Research and Development.

General Britton, have you a prepared secret report?

General BRITTON. That is correct, sir.

The CHAIRMAN. We will be glad to hear from you, sir.

STATEMENT OF BRIG. GEN. F. H. BRITTON, DIRECTOR OF DEVELOPMENTS, OFFICE OF CHIEF OF RESEARCH AND DEVELOPMENTS, U.S. ARMY

General BRITTON. Mr. Chairman, I have some slides I would like to use, and I asked Major Pierce to show them for you.

The CHAIRMAN. All right.

General BRITTON. I may have to move back a bit from the table as we get to the slides.

Mr. Chairman and members of the committee: I want to thank you for this opportunity to speak to you in executive session because it gives me the opportunity to explain to you our most ambitious project that utilizes the ground cushion phenomenon. The other day, Mr. Macauley, Deputy Director of Defense, Research and Engineering, described to you the various classifications of ground cushion phenomenon air vehicles. He spoke about the air vehicle riding on air but after attaining a minimum velocity. It is this type of vehicle that I am going to speak about now.

First, however, I would like to explain the sensitivity of this project. We refer to this project, which is jointly sponsored by the U.S. Air Force and the U.S. Army, as the AVRO project. The vehicle itself is called the AVROCAR.

The Army intends to use this type of vehicle in tactical operations as I described them in the unclassified portion of this presentation. This slide is an artist's concept of one possible use of the AVROCAR.

Gentlemen, this system could provide the U.S. Army with a potent Vanguard immediately available in any limited war in the future. I hope I have been able to convey to you the reason for the Army's enthusiasm for this concept of air vehicle. Because of its unique features and potential performance, I believe you can see why we want to maintain its classified status as long as possible. If you have any questions, we will be happy to answer them now. And we have some people here that can help on some of the technical questions.

The CHAIRMAN. As I understand from you, General, the Army is more than simply exploring here. You are actually enthusiastic in feeling you have something which has already been partially tested out.

General BRITTON. Yes, sir.

The CHAIRMAN. Therefore, the Army proposes to complete this research program, going right ahead with it.

General BRITTON. Yes, sir. It is one of our high priority programs.

The CHAIRMAN. Is it for the next fiscal year?

General BRITTON. Yes, sir, we will have money in it.

The CHAIRMAN. How much money will you have in it next year?

General BRITTON. At the present time we have spent from the Army funds, and there were funds previous to this devoted to the research. We have presently $2.1 million. We have funds for continuing this and the testing for $1.9, and the planned 60—and I only say planned—is another $1 million.

In other words, it is a total of the Army money over the 3 fiscal years of 85 million.

The CHAIRMAN. Five million?

General BRITTON. * * *

The CHAIRMAN. Of this year?

General BRITTON. That is correct, sir.

The CHAIRMAN. You think this research would be completed about when?

General BRITTON. * * *

The CHAIRMAN. * * *

General BRITTON. * * *

The CHAIRMAN. Is this item in the public works bill? It is not in the public works bill coming up this week, is it?

General BRITTON. No, sir. Not to my knowledge.

The CHAIRMAN. How is it carried, then?

General BRITTON. It is carried in the Army appropriations, sir.

The CHAIRMAN. With a general authorization?

General BRITTON. Yes, sir. It is in our air mobility program, Department of the Army, Funding.

The CHAIRMAN. You call this an air mobility program?

General BRITTON. Yes, sir. We consider this as a flying machine.

The CHAIRMAN. You consider it as a flying machine. The civilians that have testified do not consider it as a flying machine. They consider it as a ground machine.

General BRITTON. Yes, sir. The Army project which we have with the National Research Associates is the ground vehicle approach, sir.

The CHAIRMAN. What elevation can this vehicle fly at? What is the maximum elevation?

General BRITTON. * * *

The CHAIRMAN. What optimum elevation?

General BRITTON. It depends on the mission. I suppose from the military that is always the answer you get, I am afraid. This actually is true, sir. We are talking in terms of the type of operations which I discussed yesterday. As I mentioned then, we are talking about 50 to 100 feet maximum. But as far as the application of this vehicle in our tactical role which will be to give the Army a capability where we do a lot of it now by vehicles, this would be—I'm saying again, 50 to 100 feet altitude.

The CHAIRMAN. This in effect would give the Army a new type of cavalry, wouldn't it?

General BRITTON. Well, sir, equipmentwise; yes, sir. Insofar as the job to be done, the mission to be done, and you might say basically the fundamental tactics, it would be much the same as we have had in the past, except we would feel we could do it better, faster, more efficiently—much more efficiently.

Mr. CHAIRMAN. Mr. Fulton?

Mr. FULTON. No questions at this time.

The CHAIRMAN. Mr. Anfuso?

Mr. ANFUSO. General, this would sort of be an airborne artillery and cavalry, wouldn't it?

General BRITTON. I would not like to use the term artillery, sir, because artillery at least from my concept, and I think of many in the service, artillery is one where you can mass your fires, you can control it, you have the flexibility of making your shift by your fire control rather than by your equipment that fires. This is a matter of massing the punch. It is the same thing that we have tried in the service over the years, as to the tank gun, the assault guns; the infantry cannon company was an example. This is the type of fire we are talking about, that that actually accompanies the assault troops. It does give us capabilities. With the work that has been done by the other services in similar types of rocket, yes, we can lay down lots of the fire that we used to do by the mortar, or the cannon company type weapon. It is in this area, rather than the true artillery, where we keep our pieces more centrally located and shift our fires and can consolidate heavy weight of fire.

Mr. ANFUSO. There is no thought of using nuclear weapons with this type of air vehicle?

General BRITTON. Sir, this is a little too early to talk about what weapons are finally going on here. The future of small tactical weapons, this could very definitely be a case. In fact, we naturally think of these things. But to say definitely there is a plan to take this vehicle and put one of these on it, I would not be free to say so.

Mr. ANFUSO. But you could use small nuclear bombs, couldn't you?

General BRITTON. I am not thinking in terms of bombs.

Mr. ANFUSO. I see.

General BRITTON. If we are operating at low altitude, you could drop one down with a long-delay fuse, and get out of the road. I am speaking tactically now, to take the advantage, you would have to project it away from you.

The CHAIRMAN. Mr. Chenoweth?

Mr. CHENOWETH. What is the practical application of this, General? What are you going to displace if you adopt this new invention?

General BRITTON. Primarily, sir, this is a piece of equipment the Army wants to use in roles where in the past we have in large respect used vehicles. For example, in our reconnaissance and security units, we use the light carriers, or light tank, or even sometimes have to use a medium tank. Our reconnaissance elements are very often in thin-skinned vehicles like jeeps, because this is an easy vehicle to operate. We are thinking in terms of some of our units to begin moving these vehicles in order to get them off the ground. As I told you yesterday, we are trying to experiment with helicopters to learn more about this approach. We are using the old concept to bring it into modern equipment. It will be off the ground, or just above it.

In fact, we would like to use the woods, terrain, and hills for cover and concealment, but still be free of their obstacle characteristics. Some of the vehicles which have been discussed this morning would be ground sensitive. You stay with the ground. We would like to not be quite that sensitive. We would like to have this flying capability to break free of this.

Mr. CHENOWETH. What would be the length of the flight? Would it be for a considerably sustained period, or just brief hops?

General BRITTON. No, sir, this could be fairly sustained on occasions, because we are getting into the area, moving in rapidly.

Mr. CHENOWETH. Would you carry the same guns as tanks carry?

General BRITTON. No, sir, because of the trunnion reactions, we would have to go to the approach of the recoilless weapons, the rockets, because that would disturb the flying status.

Mr. CHENOWETH. Where are you doing the work on this?

General BRITTON. The contract is with AVRO, Ltd., of Canada, who were the ones that first came up with the real design perimeters on this.

Mr. CHENOWETH. Where is the actual work being done?

General BRITTON. In Canada, that is on the actual vehicles.

Mr. CHENOWETH. Not in this country?

General BRITTON. Not now.

Mr. CHENOWETH. You say it is still in the experimental stage then?

General BRITTON. We are building our first test vehicles.

Mr. CHENOWETH. I see. That is very interesting. Thank you very much, General.

The CHAIRMAN. Mr. Mitchell?

Mr. MITCHELL. General, the use of this would supplement the paratroops, wouldn't it?

General BRITTON. * * *

Mr. MITCHELL. * * *

General BRITTON. * * *

Mr. MITCHELL. * * *

General BRITTON. * * *

Mr. BASS. Would you yield?
Mr. MITCHELL. Yes, I would be happy to.
Mr. BASS. * * *
General BRITTON. * * *
Mr. BASS. That is the maximum?
General BRITTON. That is all it is right now.
Mr. MITCHELL. * * *
General BRITTON. That is correct, sir.
Mr. MITCHELL. * * *
General BRITTON. * * *
Mr. MITCHELL. I realize that.
General BRITTON. * * *
Mr. FULTON. Will you yield?
Mr. MITCHELL. Yes.
Mr. FULTON. Have you ever thought of operating these by remote control on the moon, while we're dreaming? What is your answer?
General BRITTON. Well, sir, there is a problem there. I don't know exactly about the atmosphere of the moon. I doubt that we would have it.
Mr. FULTON. You're dreaming.
General BRITTON. That would be fine to operate. From what we know this doesn't look too prosperous there.
The CHAIRMAN. Are we dreaming or actually are we dealing in something that is about to come true?
General BRITTON. We are building them.
The CHAIRMAN. That is what I thought.
General BRITTON. * * *
Mr. FULTON. One short question further if I may.
Do they have to be manned? Possibly they could be run by remote control better than being manned and you would save that much weight. Couldn't you have a system of nuclear weapons that you were able to operate from a remote control command panel?
General BRITTON. We can drone them. However, we have flown droned helicopters. We are working on drone surveillance devices, we have target drones, all of which can be controlled from remote sources. There is one problem in using it in the Army's environment in security and reconnaissance, you get into a problem of target acquisition, it is hard to replace the eyeballs in spotting your targets.
Mr. FULTON. On the question of eliminating paratroopers, if you droned these type of vehicles on landing you would eliminate the need for marines aboard when they came into the intense fire. Maybe a thousand of these would come up like ladybugs or caterpillars, with nobody on them. Is that possible?
While we are talking in fancy, is that possible?
General BRITTON. You can deliver a certain amount of firepower by that method. I don't know how much of it would be just sheer waste, in agricultural development as you went over the area. I believe some droning, and we intend to do some droning in other types, and we will certainly follow it up in any such application as this, but we are really getting into the problem, can we, by mechanical means, replace the marine or the infantryman? I personally haven't—I can only state my own opinion. I don't see this in the end. You still end up by having to get that final man on the ground in there, in my opinion.

Mr. FULTON. My observation is if you don't start flying them, you may lose them to the Air Force.

Mr. MITCHELL. What fuel do you use in your testing?

General BRITTON. * * *

Mr. MITCHELL. Concerning consumption: Are you utilizing this ground cushion effect? Do you use considerably more fuel?

General BRITTON. Of course, you can't measure that in miles. Generally speaking, whenever you take anything and start lifting it by brute strength. We have shown the picture of the ducted-fan principle. We got lift here, but we must maintain lift by continuing to push air down. This requires fuel.

Mr. MITCHELL. Thank you very much. That is all.

The CHAIRMAN. Mr. Osmers.

Mr. OSMERS. Mr. Chairman, I just want to ask General Britton a couple of questions.

This vehicle, then, would not fall specifically into ducted-fan air-bearing or peripheral jet, as we heard it described this morning?

General BRITTON. * * *

Mr. OSMERS. Yes.

General BRITTON. * * *

Mr. OSMERS. * * *

General BRITTON. * * *

Mr. OSMERS. At what altitude do you estimate you would have to get before you could start forward motion?

General BRITTON. * * *

Mr. OSMERS. Can you lift straight up and hover?

General BRITTON. Yes, sir.

Mr. OSMERS. Within the limits of your fuel consumption.

General BRITTON. I would like to bring this—when we start these characteristics of fuel consumption, I would like to bring it into the specific air vehicle we are building.

Mr. OSMERS. You can estimate almost anything, but what do you anticipate?

General BRITTON. * * *

Mr. OSMERS. * * *

General BRITTON. * * *

Mr. OSMERS. * * *

General BRITTON. * * *

Mr. OSMERS. Isn't that an engine we are now using? Aren't we now using that?

Major DOWNHILL. * * *

Mr. OSMERS. * * *

General BRITTON. * * *

Mr. OSMERS. * * *

General BRITTON. * * *

Mr. OSMERS. What sort of a range do you expect to have in your test vehicle in miles?

General BRITTON. That again depends on the payload.

Mr. OSMERS. Do you feel, General, this is always a self-serving question to ask a military man—do you feel you have enough money to handle the program?

General BRITTON. On this, sir, we do. We feel we have given this the optimum funding. It is coming along very well to give us the

information we need. I don't know if in the future I can answer the question in the same way, if we really get down to trying to build and buy.

Mr. OSMERS. That is all I have, Mr. Chairman.

The CHAIRMAN. Any further questions?

Mr. Wolf?

Mr. WOLF. Is there anyone from AVRO here who has anything else to add on this program?

Colonel HAYNES. No, sir.

General BRITTON. No, sir, there is no one here from AVRO.

Mr. WOLF. There is no one here from AVRO?

General BRITTON. No, sir. If your committee so desired, it could be arranged.

Mr. WOLF. I was wondering if we can't do that. Is there someone here who would like to comment on what the relationship of this project and * * *

Major DOWNHILL. * * *.

The CHAIRMAN. Major, may I interrupt you? You are with the Air Force?

Major DOWNHILL. Yes, sir.

General BRITTON. This is a jointly sponsored project.

The CHAIRMAN. This is jointly sponsored with the Army?

Major DOWNHILL. Yes, sir.

The CHAIRMAN. All right.

Major DOWNHILL. That pretty much brings it up to date.

This is the nature of the Air Force interest.

Mr. ANFUSO. Mr. Wolf, would you yield to me?

Mr. WOLF. I would be happy to.

Mr. ANFUSO. Major, or General, on this AVROCAR, are we dealing here with a patented item?

Major DOWNHILL. There are several basic patents that have been allowed and agreed to in the contracts with AVRO as belonging to them. The exact nature of them I'm not really qualified to discuss, but they involve the way in which they produce this curtain of air and their stabilitization, and things of this sort.

Mr. ANFUSO. In other words, the patents dealing with this AVROCAR are owned by a foreign company, aren't they?

Major DOWNHILL. Yes. They are in fact, the several patents on which the thing is based, are owned by the AVRO Co., or some relationship between AVRO and their inventor.

I'm not prepared to discuss that.

Mr. ANFUSO. Assuming that both the Army and the Air Corps would like to go into production. How are you going to handle that situation?

Major DOWNHILL. Well, we have had repeated assurances, and I think the Army has had the same, in discussions with AVRO aircraft top management and still further the A. V. Roe Canada, Ltd., which is the holding company, that when the time came there would be mutually agreeable arrangements made. This could involve many things, such as our interdependence agreements with Canada, the share production all sorts of things would be involved. None of the details have been worked out. Our people in the Air Force, and I I think the Army, are confident that they can be worked out satisfactorily.

Mr. ANFUSO. The manufacturing may have to take place in Canada, or if it takes place in the United States, the AVROCAR Co., or rather the AVRO Co. could tie you up with all sorts of conditions.

Major DOWNHILL. Well, there is certainly this element, but we don't believe that it would manifest itself in this way.

The CHAIRMAN. Now, let's go ahead with the discussion.

General BRITTON. In relation to your last question, there is one item about this question of patents which I think that the contractor agrees to grant the U.S. Government the option and request of the Government, a licensing thereunder to any patents that may issue therefrom at a reasonable royalty rate hereinafter to be negotiated. In other words, we would not be locked into AVRO.

Mr. ANFUSO. Mr. Chairman, I would like to offer the suggestion that this subject is extremely important. This AVROCAR may be of tremendous use, and has great potentiality in war and in peace. Perhaps some subcommittee of this committee should look into the contracts already made and study them.

The CHAIRMAN. Couldn't you give us, General, a memorandum for our staff as to the amount which we are spending on programs from the Army, Air Force, and the Navy; too, does DOD come into this in any way?

NOTE.—Information on names of contractors, scopes of contracts, costs and results except for classified Army-Air Force and Air Force contracts was inserted in the transcript of hearing for April 14, 1959, by the Department of Defense.

General BRITTON. Not moneywise.

The CHAIRMAN. We would just like to know. We understand that that is secret information, and will be available only to the staff and to the members of the committee. Now your contracts are all with AVRO Co.

General BRITTON. That is correct, sir.

The CHAIRMAN. Is that the case with you, too?

Major DOWNHILL. There has been some subcontracting, sir.

The CHAIRMAN. That is through the AVRO Co., isn't it?

Major DOWNHILL. Yes, through the AVRO Co., in connection with the AVROCAR they are subcontracting the propulsion system to their own subsidiary—not subsidiary, but cocompany in the combine of Orenda Engines, just across the street from them.

The CHAIRMAN. That would clear it up, if you give us the overall picture.

General BRITTON. We will be glad to do so.

The CHAIRMAN. Any further questions?

Mr. MOELLER. May I ask a question: Will the testing also take place in Canada, General?

General BRITTON. The initial flights, of course, will take place there. The wind tunnel testing will take place at Ames Laboratories, at Moffett Field, in California.

Mr. MOELLER. General, do you feel the security there is good enough to handle something as promising as this is?

General BRITTON. Once we get this out and start flying it, the general configuration—this is why we say we have got to announce something on the general configuration. Once we start getting out of the

security of buildings, the fact of its shape and the fact it flies, we won't be able to—we will have to say something.

Mr. MOELLER. Is that even necessary to announce too much of this too early?

General BRITTON. We don't want to, any more than we can help it, sir. We want to hold back. Once these things start flying it is going to be hard to do it, because again if we don't say what it is, we are going to get a lot of speculation. We will be back into flying saucers again.

The CHAIRMAN. Mr. Osmers?

Mr. OSMERS. A point of general inquiry, not necessarily of this witness. I am a little confused in my mind about the classification of what we heard here today. Some of this seems to me is public information which I have seen in magazines of general distribution, this type of vehicle, and yet I notice the precaution the General has in his earlier statement. Hasn't there been considerable speculation, Mr. Chairman, in regard to what we are doing in this field, generally circulated magazines, and published books?

General BRITTON. In the early part of the presentation, sir, you remember the three charts, where they talked about the different types of lifts, this is in open literature, it is not classified. The specific configuration, particularly the method of controlling the air flow as we had in the slides that I was showing here, * * *.

Mr. OSMERS. In other words, Mr. Chairman, the specifications of the actual vehicle under construction by AVRO are secret, but the fact the Army, the Air Force, and our Government has a great interest in various forms of vertical lift and flight is not in a secret category?

General BRITTON. No, sir.

The CHAIRMAN. General, as I understand it, through the active interest of the Army and Air Force in this, it is classified, isn't that correct?

General BRITTON. Sir, I would like to quote from my unclassified testimony of the other day, which I believe will help put this in focus to more or less indicate the announced, nonpublic information that we have actually presented.

I make reference to the joint Army-Air Force sponsored program to develop a VTOL research vehicle with AVRO Aircraft, Ltd., of Canada, which makes use of the ground cushion phenomenon. This research vehicle known as the AVROCAR appears to offer a great potential to the U.S. Army for increasing its mobility in the combat area. The AVROCAR will have a hovering capability, as do other ground effect vehicles, but it will have a much higher performance outside the ground cushion than the ducted-fan research vehicle which I have previously mentioned. This development is now in the advance stages and we expect to start ground testing sometime in the near future. This much, because of certain other announcements, and the fact that contracts are known to be had with AVRO, was necessary.

The CHAIRMAN. That clears it up. When you keep out of technicalities and specifications, it is not classified.

General BRITTON. That is correct, sir.

The CHAIRMAN. Thank you.

General BRITTON. We tried to keep quiet that it was a disc vehicle. But this seems to be getting known.

The CHAIRMAN. That is not possible. Mr. Anfuso?

Mr. ANFUSO. General, how do we know that the Canadian company is not making this information known to other countries? Do we have any agreement with the Canadian company that all this research is kept secret between that company and the United States?

General BRITTON. Sir, this is because of our agreements with Canada and our work with them, and their work through the defense research board, they run through a clearance procedure, and a security classification very similar to ours, and we work on a government-to-government basis to help maintain the security of this type of information.

Mr. ANFUSO. We have no assurance that the Canadian Government is not dealing with any other country. I mean it could be a friendly country.

General BRITTON. I realize that, sir. Of course, we have their statements, and we have the agreements which we have made—the interdependence agreements.

Mr. ANFUSO. It is very important, I think, that this committee examine those agreements. You would have no objection to that, would you?

General BRITTON. Sir, these agreements are not within the cognizance of the Department of the Army to control, because they go clear back to the President's interdependence agreements, of November 6, 1956.

Mr. ANFUSO. You would have to get the consent of that group?

General BRITTON. It is not an Army problem, it is entirely under the Government. We deal in our various agreements with the Canadian Government as we have a very interlaced security control system.

Mr. OSMERS. Mr. Chairman, the question, the last question by the gentleman from New York brings up another question which may be beyond the ability or knowledge of these particular witnesses to answer.

Do we have, Mr. Chairman, any other important programs of a similar nature, that is of a classified nature going on in Canada at this time without specifying what they may be?

Do you know of any other programs?

General BRITTON. Sir, I would like to speak to this of my personal knowledge to give you an indication of your answer without actually naming the projects. Under the Canadian, United States and British Armies, under international agreements, have a system of standardization, we sometimes refer to it as the ABC standardization program, in which we exchange information, and in fact the classified information or projects, that are withheld from this is small in number. Our military characteristics of standard army equipment, we work very closely when we set those up, and right through. A lot of equipment that they are interested in, they follow the projects very closely. We follow theirs. From this we hope to get more standardized military equipment. It was the outgrowth of this that the NATO cartridge was adopted. The 155-millimeter gun is becoming quite standardized in the service. Although the British have not yet gone into it,

they are testing it now to see if they can work it into their system. There is quite an exchange within the Army. We also, of course, have the mutual-weapons systems whereby certain foreign countries have requested United States support which we examine to see if they have compatibility with the military problem. These were sometimes supported. There is a certain amount of information that has to be exchanged here. This is on a much lower order than the type you are talking about.

Mr. OSMERS. You don't know of any similar secret research and development project—American project—conducted in Canada?

General BRITTON. I am sure there are many other projects that are of a classified nature.

Mr. OSMERS. I have no further questions.

The CHAIRMAN. There are no further questions. We want to thank you, General, very much; you too, Major, and all of you, for coming here.

The committee will accordingly be adjourned subject to call.

(Whereupon, at 12 o'clock noon the committee was adjourned to reconvene at the call of the chairman.)

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